

## ENVIRONMENTALLY RESPONSIBLE ENERGY PRICING

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## EXECUTIVE SUMMARY

1. The purpose of this report is to ascertain the energy prices needed to reflect the environmental costs imposed by energy, thus providing economic incentives for energy usage that will reflect the full social cost.
2. The energy sources included in the analysis are: coal, gasoline, diesel oil, airplane fuel, heating oils, natural gas, and wood. Nuclear energy is not included, because of the absence of reliable social cost estimates, not because of a belief that these costs are low. Wind, solar, and geothermal energy are also excluded, but their social costs (i.e., externalities) should be minimal.
3. The principal externalities considered are those related to air pollution and acid rain. Energy effects on climate change are not included. The estimates consequently provide the basis for a “no regrets” energy policy, as they establish a lower bound on the appropriate energy price that reflects both the private costs of production and the social costs arising from energy usage.
4. The approach taken in this report is to analyze the cost subsidy currently given to energy users because they are allowed to diminish environmental resources without paying any resource cost. By calculating the damage inflicted by different energy sources, it will be possible to ascertain the user fee that must be charged so that energy users will fully recognize the environmental consequences of their actions.
5. The approach we use to set the user fee levels is to determine the unit externality cost values for emission reductions from the current level to a strict compliance with the current EPA regulatory standard. Earlier analyses of the benefits associated with EPA regulations are used to establish the appropriate price that must be charged for different types of environmental damage. These unit values are then applied to assess the externality costs between the level of the EPA standard and a background level of pollution.
6. The six sources of externalities considered in our analysis are the following: lead in gasoline, air toxics from motor vehicles, particulate, sulphur oxides excluding SO<sub>2</sub>, mortality, sulphur oxides SO<sub>2</sub>, mortality, and ozone.
7. The principal source of pollution costs varies with the particular energy source: gasoline (particulate), diesel (particulate), aircraft fuel (particulate), wood (particulate), coal (sulphur oxide mortality), and natural gas (ozone).
8. In setting the appropriate user fees, credit should be given to energy users for the charges they currently pay above the private costs of energy. These charges consist of various energy taxes, which serve in part as a user fee that discourages energy use and reflects some of the external social cost. These energy taxes are substantial. The largest taxes are on gasoline (\$26.9 billion) and coal (\$10.2 billion). As a percent of price, the largest taxes are on coal

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(38 percent), diesel fuel (27 percent), and gasoline (25 percent). Many of these taxes are returned as subsidies (e.g., the highway trust fund). After netting out these subsidies returned to users of the energy source, the highest net taxes are on gasoline (\$18 billion) and coal (\$10 billion). As a percent of price, the largest net taxes are on coal (36 percent) and gasoline/diesel fuel/aircraft fuel/fuel oil (13-17 percent).

9. The report develops energy user fees under a variety of assumptions. The estimates presented below are the midpoint assessments for two variants --25 percent reduction in emissions due to current regulations and 10 percent reduction in emissions. These two scenarios reflect the influence of the extent of the emissions reduction that will be achieved by existing regulations. The greater the gains that will result from regulation, the smaller are the environmental costs that will be generated by the remaining pollution levels. A summary of the results appears below:

Fuel Type	Units	Current Net \$Taxes as a Percent of Price	Externality Cost as a Percent of Price
Gasoline	gallon	16.6%	16.7%
Diesel fuel	<b>gallon</b>	<b>12.9</b>	<b>50.4</b>
Aircraft fuel	<b>gallon</b>	<b>15.5</b>	<b>12.9</b>
Heating Oil	<b>gallon</b>	<b>14.6</b>	<b>63.7</b>
Natural Gas	1000 cubic feet	6.4	1.1
Wood	short tons	0.0	152.4
Coal	short tons	35.9	528.0

Coal and wood are the greatest outliers in terms of the disparity between the current tax level and the user fee that should be imposed to capture the full social costs.

10. Figure 2.1 summarizes many of the key findings of the report with respect to current tax levels and the range of estimates of the externality damages.

11. A carbon tax is not ideally suited to addressing these externalities since the pollution damages are correlated in different ways with carbon content. The full social cost prices could, however, augment a carbon tax but the levels of these charges should vary by fuel type. Specific estimates of these amounts are provided.



12. The demand for residential energy and its associated pollution also maybe inefficient because of housing tax subsidies.

13. The tax subsidy for housing capital has two effects on residential energy demand. First, by lowering the price of housing services, the tax subsidy increases the demand for housing services and the associated energy. House size is strongly related to energy demanded for space heating and cooling. Second, the subsidy for housing capital creates an incentive to substitute capital for energy in the production of housing services. This substitution effect encourages the purchase of energy-efficient capital (e.g., insulation).

13. Eliminating the tax subsidy for housing would increase the cost of housing capital by 23 percent, lower the demand for housing services by 11.8 percent, and residential energy demand by 6.8 percent. Alternatively, a 20 percent tax on residential energy would result in the same reduction in residential energy demand. Only eliminating the personal tax advantages of owner-occupied and rental housing would reduce residential energy demand by 3.2 percent. Only eliminating the deductibility of mortgage interest and property taxes for owner-occupiers would decrease residential energy demand by 2.1 percent.

14. These possible reductions in residential energy demand should be weighed against the increases in energy demand associated with the increased consumption of and production of other goods which would occur because of the switch from housing to other goods. Since housing is not a particularly energy-intensive good, these increases in energy associated with other goods might result in total energy demand not changing.

## A READER'S GUIDE

The purpose of this report is to assess various aspects of the pricing of energy, with the ultimate objective being to determine how energy can be priced to promote its efficient utilization in the presence of the environmental externalities generated by energy. The environmental damages considered will be limited in scope. In particular, we will focus on conventional externalities associated with traditional forms of pollution regulated by EPA as opposed to the more controversial externalities linked to global warming.

Part I of the report provides an introduction to the full social cost energy pricing issue. Why is it that energy prices may not correspond to their efficient level, and what are the broad classes of external damages that must be taken into account?

Part II of the report represents the key component of the analysis. In it we outline the taxes paid by different sources of energy and compare these taxes to the appropriate tax amount that should be levied to take into account the external damages associated with each particular form of energy use. Concerns such as this are not entirely new. They have been raised by academics, by government organizations such as the National Academy of Sciences, and even by presidential candidates. What is new is that this report documents the appropriate level of taxes to bring the prices for these energy sources in line with their true cost to society. Perhaps the most surprising aspect of these calculations is that it is necessary to move beyond the myopic focus on a gasoline tax and consider more broadly-based charges that can be imposed on energy to reflect the associated environmental damages.

Appendix 2.1 provides a more detailed discussion of how the full social cost energy prices were calculated. This more technical assumption is intended to delineate the assumptions involved in the analysis as well as the specific EPA documents on which these estimates were based.

Appendix 2.2 considers related issues of less prominence, such as the relationship of our results to the Draft New York State Energy Plan.

Part III of the report addresses implementation issues. In particular, what different tax mechanisms are available to impose full social cost energy prices, and what are the comparative advantages of using these different tax schemes? Appendix 3.1 provides related tax tables.

Part IV of the report represents a departure in terms of the focus in that the market failure being addressed is not the external damages caused by energy but rather the implications of the variety of tax policies for housing that may distort energy usage. In particular, if these tax policies lead consumers to use an amount of energy that is more than efficient, then it may be the case that the government has in place policies that actually

encourage energy use beyond its efficient level rather than discourage it. Thus, the task of an appropriate energy pricing scheme is not simply to correct for the damages inflicted by energy usage, but also to rectify the impact on the environment caused by government policies that foster energy usage. The housing analysis in Part IV indicates that these influences on energy usage are indeed quite substantial.

## **PART I:**

# **OVERVIEW THE FULL SOCIAL COST' ENERGY PRICING APPROACH**

Ideally society wants to promote efficient utilization of all resources. The nation's energy resources are among those for which we would like to establish efficient utilization. This concern is particularly great since energy consumption has been linked to a number of important environmental costs principally relating to air pollution. Because energy users do not pay for these costs, they are labelled as "externalities" by economists.

In any market context, it is desirable for economic actors to bear the full consequences of their actions so that their behavior will incorporate the social effects as well as the private benefits. In the case of energy usage, the consumers are not paying these costs since they are permitted to use an environmental 'resource without paying any explicit fee.

The economic objective is twofold. First, we want all energy producers to be supplying the appropriate amount of each form of energy given these social costs, and we want consumers to be consuming the amount of each energy source that reflects a balancing of the benefits to them of the energy and the social costs of their actions. To achieve this objective, which economists term an efficient energy usage objective, the incentives for energy production and utilization must be correct.

Consider, for example, the situation of a representative firm that produces energy. There is some level of energy production that represents the amount of energy that should be produced after recognizing the market value of the energy and all of the costs associated with energy production. This energy output level can be achieved in two ways. First, one could establish an environmental quality standard that ensures that the production or usage of energy resulted in the level of pollution that balances the benefits and costs of pollution reduction appropriately. Alternatively, one could charge a user fee for energy usage to promote the efficient outcome.' One can achieve the objective of having the firm generate the efficient amount of pollution using either a user fee or a standards approach. The emphasis of the U.S. Environmental Protection Agency and other regulatory agencies has been on the promulgation of regulatory standards.

Standards are also attractive to firms in that they involve lower compliance costs than do pollution fees, if these fees are imposed on all pollution, not just pollution above some regulatory standard. Under a standards regime, a firm must pay for the cost of meeting the standard, but once the standard has been met the firm does not pay for any of the pollution that it generates. Thus, in effect, the firm receives a free right to pollute up to the efficient level of pollution, and it is not charged for this pollution. In contrast, pollution fees that do not give firms some free pollution rights but will impose costs associated with control devices as well as additional fees imposed for whatever pollution remains after the control devices have been installed.

Although environmental standards promote short-run efficiency in terms of

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establishing the correct amount of pollution for any given firm in the industry, they do not establish incentives for long-run efficiency. In particular, the incentives to enter polluting industries are too great because firms do not have to pay for the implicit subsidy they receive by not internalizing the costs of the pollution that they generate. Pollution levels up to the standard are free to the firm, but impose real societal costs.

The focus of this report will be on establishing user fees that will lead energy users to incorporate the environmental costs of energy in their energy choices. The approach will be to determine what the price of energy should be to internalize all the costs and subsidies involved in the energy resource area. This calculation will indicate the appropriate user fee level that will give both consumers and producers the correct price incentives. However, because of the character of this form of policy the energy user fee will also provide correct economic incentives for long-run entry into the industry.<sup>2</sup> Thus, the overall purpose of this study is to establish a policy that economists would term an efficient energy policy.

This objective is obviously quite ambitious and obtaining a definite assessment could ultimately require a major resource commitment by EPA -- far greater than the cost of the current study. Because of resource constraints, the scope of this study will necessarily be more limited than this and, as a result, the analysis will adopt several simplifications. We will highlight the major features of our approach in the first section of the report. A detailed Appendix describes the methodology in greater detail. It should be emphasized that this research remains a work in progress. Additional research is underway to determine how use of an externality tax approach can be incorporated in a policy context in which command and control regulations are in place. Moreover, other second-best factors also enter. Housing tax subsidies distort energy usage, as the final part of this report indicates. Thus, eventually we hope to address the net effect of all market imperfections on the efficient utilization of energy, recognizing that society's objective is to achieve the proper amount of pollution control.

The emphasis will consequently be on only a subset of the adverse externalities created by energy. The most notable exception is the omission of the global warming externalities from the analysis. The reason for this omission is not that we believe these externalities to be unimportant. Rather, the magnitude and direction of the greenhouse effect impacts are now being debated in a number of arenas. One of the dividends of our analysis is to begin the process of ascertaining how much we can achieve the objectives of those who advocate policies to address the risks of climate change by adopting a user fee approach that recognizes externalities other than those associated with climate change.

This policy approach has already been widely discussed in the global warming literature. Some observers have designated the policy approach we are adopting as the "bootstrap" approach or the "no regrets" approach. As a society, we know we should go at least this far unless global warming will, on balance, be beneficial. Thus, our analysis is

intended to solve the problem of ascertaining what user fee is needed to promote appropriate energy utilization, assuming that we did not take into account the role of climate change. These are the minimal measures that society should undertake to address the problems of climate change.

In subsequent project periods, we will explore the degree to which our broader climate change policy objectives can be achieved through appropriate recognition of the other externalities associated with energy usage. In particular, to what extent will a no regrets approach achieve the objectives of a more ambitious climate change policy?

## 1.1. BASELINE ESTIMATES

It is useful to put the scope of our analysis in perspective by comparing the focus of our study with a more wide-ranging study of energy externalities. Table 1.1 provides a summary of the estimates prepared by Darwin Hall in his article, "Social and Private Costs of Alternative Energy Technologies," Contemporary Policy Issues, July 1990. For the most part, this article does not overlap the categories that we are assessing using EPA benefit studies. This report does not consider wind, solar, geothermal, or nuclear power. The primary source of overlap is for natural gas, oil, and coal, where the overlap is in the areas of air pollution and acid rain. In these cases, we will rely on the EPA studies that we have compiled rather than adopting the approach used by Darwin Hall.

The omission of wind, solar, and geothermal power from our study is not consequential. These energy sources are believed to create few externalities. In contrast, the failure to assess the externalities associated with nuclear power are more problematic. The potential hazards posed by nuclear energy cannot be ignored simply because we lack good data on their magnitude.

The main reason why externalities can be assessed for environmental pollutants is that there are available building blocks for analysis. We observe emissions levels and, with the aid of health benefit assessments, can make some judgments pertaining to likely impacts.

Assessment of the costs of nuclear power is a quite different enterprise. In the absence of an EPA risk assessment for nuclear power or a comparably detailed regulatory analysis, we will exclude nuclear power from the analysis. We would not, however, wish our results to provide a relative subsidy to nuclear power simply by default. It would not be correct to impose energy user fees on only wood and fossil fuels and to leave nuclear energy affected. Before any energy user fee approach is implemented, there should be a comparably vigorous assessment of the expected externality costs associated with nuclear energy.

For the three major energy sources in Table 1.1 that we do consider -- natural gas,

Table 1.1  
Damage Computation in Hall Study

Cumulative Estimates of External and Total Social Costs or Energy (dollars/unit of energy)								
Source of Energy Service	Consaervation Efficiency	Wind	Solar	Geothermal	Natural Gas	Oil	Coal	Nuclear
Water Pollution	0	0	0	Minor	0	Omitted	Omitted	Omitted
Solid Waste	0	0	0	0	0	Omitted	Omitted	1988\$ AC: 0.07¢/kWh
Air Pollution and Acid Rain	0	0	0	Minor	1988\$ IB: \$0.286/ MMBTU	1985\$ IB: \$11.59/ BBL	1985\$ IB: \$16.80- \$18.77/Ton MC: \$7.23- \$7.67/Ton	
Green House		0	0	0	1988\$ MC: \$0-\$2.56/ MMBTU	1988\$ MC: \$0-\$3.48/ BBL	1988\$ MC: \$0-\$4.50/ MMBTU	
National Security		0	0	0	Substantial Reserves: Soviet Union and 1 ran	1985S AC: \$5.79/BBL AB: \$4.20- \$7.07/BBL	0	1986\$ AC: 0.85¢/kWh
Nuclear Insurance Subsidy	0	0	0	0	0	0	0	1985\$ AC: 0.49¢/kWh
Reactor Loss	0	0	0	0	0	0	0	1987\$ AB: 0.14¢/kWh
Additional Safety	0	0	0	0	0	0	0	1988\$ AB: 0.16c- 0.94¢/kWh
Cumulative External cost (1989 \$)	0	0	0	Minor	\$0.30-\$2.85/ MMBTU	\$16.85- \$22.14/ BBL	\$13.68- \$124.75/ Ton	1.9¢-2.7¢/ kWh
Private Cost (1989 \$)	0.5¢-2¢/kWh	8¢-10¢/ kWh	9¢-12¢/ kWh	5¢-11¢/ kWh	\$2.50-\$3.00/ MMBTU	\$15-\$18/ BBL	\$35-\$45/ Ton	14¢-16¢/ kWh
Total Social cost (1989 \$)	0.5¢-2¢/kWh 36¢/Gallon Gasoline	8¢-10¢/ kWh	9¢-12¢/ kWh	5¢-11¢/ kWh	\$2.80-\$5.85/ MMBTU	\$32 -\$40/ BBL	\$49-\$170/ Ton	16¢-19¢/ kWh

Notes: IB=Incremental Benefit; AB=Average Benefit; AC=Average Coat; MC=Marginal Cost; BBL=Barrels of Oil, 42 gallons or 6 MMBTU; Tons of Coal=2,000 pounds or 24.7 MMMBTU; MMBTU=MillionBritish Thermal Units; tc/kWh=cents per killowatt hour levelized over the life of a typical unit; M-Ton=Metric Ton=2,200 pounds.

Source: See Hall (1990) for further explanation of the calculations.



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coal, and oil -- we will focus on the air pollution and acid rain costs. We will abstract from greenhouse effect costs and national security costs. Each of these costs is very uncertain. The precise allocation of defense costs is particularly difficult to assess because of the multiplicity of our defense policy objectives.

It is instructive to consider each row of Table 1.1 in turn. The first effect that Darwin Hall considers is that of water pollution. He indicates negligible externalities associated with the various energy sources so that omission of this component from our analysis will not have a major effect on the results. The second row of the table pertains to solid waste pollution. With the exception of nuclear energy, this is also not a significant component.

The third row of Table 1.1 deals with air pollution and acid rain. This is the emphasis of our study and also the largest cost component in Hall's study. The estimates that Hall developed will not be as reliable as those that can be obtained from the standpoint of national EPA policy. In particular, his report uses the unit benefit values derived from pollution in California, principally in Los Angeles. In contrast, our estimates will rely on national estimates of the air pollution costs of energy usage. Moreover, our assessment will be much more comprehensive in terms of the particular types of pollutants that we consider. This difference with the analysis by Hall is not a minor variant. In particular, the largest externalities associated with energy usage are those linked to air pollution and acid rain. The main adverse effects of acid rain are in the Eastern states so that a study based on California benefits will not capture this influence. To provide an entirely different analysis of these important benefit components as we do in this report is, in effect, to prepare an almost completely separate assessment of the energy externalities.

The fourth row of Table 1.1 pertains to the costs associated with climate change. As is indicated above, there remains substantial debate over the magnitude and even the direction of these effects. Our analysis will exclude these from consideration, not because they are unimportant, but because the focus of our analysis is to determine the pricing of energy that is required to achieve efficiency if we take into account factors other than global warming. In subsequent project periods we hope to address the global warming issue more fully.

The next row of the table pertains to national security. There remains substantial uncertainty over the appropriate allocation of defense costs to energy. To what extent was the war in the Persian Gulf intended primarily to influence the energy price as opposed to promote other policy objectives? In the absence of making such an allocation, the costs of operations Desert Shield and Desert Storm cannot be allocated to gasoline and related petroleum energy sources. There is no doubt an important linkage of such defense costs to energy, but the extent of this linkage is unclear. Moreover, the overall magnitude of the ultimate expenditure that the United States will incur is not yet determined. Even more uncertain is the extent of our future obligation. As a result, this analysis will focus on the

air pollution effects of energy rather than on the national security effects.

The final externality component of the analysis by Hall consists of the assessments of the various aspects of nuclear energy, which lie outside the scope of our report.

## 1.2. ENVIRONMENTAL EXTERNALITY BENEFITS

The main focus of this report is to establish the environmental costs associated with various types of energy usage. All the estimates that will be discussed below are derived from benefit studies done for the U.S. Environmental Protection Agency. It is helpful to review the methodology that we are using since we hope that EPA officials will continue to comment on the appropriateness of our selection of various empirical estimates from the available range of possible EPA estimates. The Appendix to this report summarizes the methodology in greater detail.

The information currently available as calculated by EPA pertains to the benefits that will be achieved by reducing current emissions to a pollution standard. The first step of the analysis is to define what this standard is and how fast it will be met. The assumption that we have adopted in consultation with the OAQPS, is the following. We have assumed that the benefits associated with attaining compliance will be achieved in one year and that they will not be phased in over a long period of time. In addition, in situations where the pollution standard is not specified in units that are comparable to those needed for assessing benefits, we perform a sensitivity analysis assuming 10 percent and 25 percent reductions in pollution will ensure compliance with the current standards. In some cases, notably lead, we do have precise information regarding the standard level so that such an assumption is not needed. However, for pollutants such as particulate, sulphur oxides, and ozone, we must make this assumption in order to establish the compliance reference point.

After having determined the unit benefit value for reducing pollution from the current level of emissions to a pollution standard, we then apply these benefit values to assess the total benefit that will be achieved by going from the current emissions level to a background level of pollutants. We then use these benefit assessments in conjunction with the total energy amount to calculate the externality per unit of energy. In some cases the units are gallons, where in others they may be tons or cubic feet. The estimates that we have prepared thus far appear reasonable given the information we have been able to obtain from the OAQPS staff in Durham, NC.<sup>3</sup>

## NOTES

1. In theory, the extensive literature in economics on the optimal Pigouvian tax is intended to provide guidance on the setting of optimal externality taxes.
2. It should be noted that the user fees should be regarded as only an initial approximation to such optimal fee levels. The theoretically correct user fee amount is based on a complex set of economic influences beyond the degree of refinement possible with available data.
3. Before considering the particular estimates, let us briefly review some of the sources that we used for our estimates. The benefit numbers for particulate, sulphur oxides, and  $\text{NO}_x$  are based on National Ambient Air Quality Standards (NAAQS) economic analyses. The ozone numbers are from an Office of Technology Assessment (OTA) study and a new study by Resources for the Future under contract to the OTA. The air toxics estimates are based on estimates derived by the Office of Mobile Sources. The lead estimates are derived from an economic analysis of restricting lead and gasoline prepared by the EPA's Office of Policy Analysis. The acid rain estimates are based on a study by the National Acid Precipitation Assessment Program (NAPAP). The air toxics numbers and the lead numbers are perhaps most reliable in that we have a well-defined reference point in computing the benefit values. Carbon monoxide and  $\text{NO}_x$  are omitted from the externality costs because of the absence of a definitive regulatory analysis of these pollutants. Because of the timing of these various studies, our estimates will pertain to 1986, the most recent year for which comprehensive estimates of externality costs could be generated.

PART II:  
THE FULL SOCIAL COST ENERGY PRICING APPROACH TO  
GREENHOUSE WARMING POLICY

## 2.1. INTRODUCTION

Policies to prevent substantial climate change will impose potentially enormous social costs to address a problem for which the character and associated consequences are highly uncertain.’ At the most extreme, some scientists suggest that prospective climate changes may, on balance, be beneficial. Many observers have consequently recommended a more cautious policy approach, at least as an initial step. Until the pertinent uncertainties are resolved, they suggest that we should follow the minimal course of action dictated by our current knowledge. The stringency of policies consequently should reflect the non-global warming damages and costs associated with emissions of greenhouse gases. This policy prescription has come to be known as the “no regrets” approach since even the most favorable informational developments regarding the risks of global warming will not undermine the desirability of taking these minimal actions.<sup>2</sup>

In other words, a “no regrets” approach is to adjust current prices to reflect all non-global warming damages associated with the emission of greenhouse gases? To ensure that society adopts the most efficient mode of energy use, which is the most important source of greenhouse gases, and that the economically efficient amount of energy will be used, the prices of these energy sources should reflect their total social costs. On the basis of this principle, the 1991 National Academy of Sciences greenhouse warming panel recommended:

Study in detail the “full social cost pricing” of energy, with a goal of gradually introducing such a system...On the basis of the principle that the polluter should pay, pricing of energy production and use should reflect the full costs of the associated environmental problems. The concept of full social cost pricing is a goal toward which to strive. Including all social, environmental, and other costs in energy prices would provide consumers and producers with the appropriate information to decide about fuel mix, new investments, and research and development.’

The results reported in this section establish a major component of the value of the full social cost prices. The environmental damages from fossil fuel use represent only a major component of the full social costs because they exclude the non-environmental social costs of fossil fuel use. Other possible cost components include: national security costs associated with ensuring uninterrupted oil imports and inefficiencies resulting from failure of electric utilities to use marginal cost pricing? Although we know of no systematic study of these non-environmental social costs, the magnitude of these costs may also be very large. The results reported here, however, pertain only to the environmental damages of fossil fuel use.<sup>8</sup>

Our assessment of the full social cost prices of energy suggests that even a “no regrets” policy involves enormous dollar stakes. Shifting our focus from climate change to

more conventional environmental effects does not eliminate the prospect of considerable economic costs. Policies based on the estimated environmental impacts would necessitate substantial expenditures, possibly hundreds of billions of dollars annually. Moreover, there is also considerable uncertainty with respect to environmental damages from energy uses other than greenhouse warming, although less so than with the valuation of global warming damages.

Even if full social cost energy pricing is never implemented, examination of these prices is a useful mechanism for identifying the divergence between private and social costs. Should our policy emphasis, for example, be on improving fuel efficiency of automobiles, or should we direct greater attention to decreasing pollution from coal? In terms of eliminating the underlying uncertainties, should analysts focus their attention on resolving the complexities of acid rain, or do the mortality risks associated with sulfur oxides represent an area in which there is much more to be learned? Examining full social cost energy prices highlights the salient open research questions as well as the broad outlines of what is currently known about appropriate pricing of energy. These issues are pertinent not only to climate change policy, but also to the debate over our national energy strategy.

## 2.2. ECONOMIC FOUNDATIONS

Ideally a society interested in the welfare of its citizens wants to promote efficient utilization of all resources, including energy resources. This concern is particularly great since energy consumption has been linked to a number of environmental costs, principally relating to air pollution. Because energy users do not compensate those who bear these costs as part of a market transaction, they represent a classic case of environmental externalities.

In any market context, it is economically efficient for participants to bear the full consequences of their actions so that their behavior will incorporate the social effects as well as the private benefits. Consumers of energy are not paying these costs since they are permitted to use an environmental resource (i.e., atmospheric waste disposal) without paying any explicit fee.

The economic objective is twofold. First, energy producers should supply the appropriate amount of each form of energy given these social costs. Second, consumers should consume the amount of each energy source that reflects a balancing of the benefits to them of the energy and the social costs of their actions. To achieve this efficient energy usage objective, the incentives for energy production and utilization must be correct.

This report estimates user fees that lead energy users to incorporate the environmental costs of energy in their energy choices.' This objective is obviously quite ambitious. Obtaining a definitive assessment could ultimately require a much more extensive

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research effort. Because of resource constraints, the scope of this study will necessarily be more limited, and substantial reliance will be placed on previous government analyses of energy-related pollution.<sup>8</sup>

The incorporation of the environmental externality costs of energy will be undertaken by relying largely upon benefit assessments that have served as the basis for EPA standards. Perhaps more than any other available documents, these assessments represent an official governmental view of the environmental damages from energy use. This is not to say that these assessments should be accepted uncritically, as they have frequently been challenged by other government agencies, academics, and industry.<sup>9</sup> Our approach provides an approximation of these environmental costs.

The estimates reflect only a subset of the adverse environmental externalities created by energy use. The most notable exception is the omission of the global warming externalities from the analysis. The reason for this omission is not that these externalities are unimportant. Rather, the magnitude and even the direction of the greenhouse effect impacts remain under strenuous debate. The intent of the “no regrets” policy assessment is to determine whether many of the objectives of those advocating policies to address the risks of climate change can be achieved through a more limited approach that recognizes only those externalities other than climate change.

This assessment of the social costs of energy embodies several simplifying assumptions. Most fundamental is that the focus of the study is on the total social costs of pollution, which will generally be lower than the social cost that firms must pay for the right to pollute. These environmental costs do take into account the role of compliance with existing regulations, but do not incorporate charges that firms now pay or will pay under EPA policies being implemented. Under the acid rain trading system, new firms in areas that have not attained their air quality standards are required to purchase permits for their pollution from firms that have reduced pollution by a comparable amount. These permit costs in effect will serve as a price that should be counted toward the firm’s payment of its full social costs.

Even when there are no permit changes, there generally are EPA regulations that frequently impose requirements that are more stringent than would be dictated on economic efficiency grounds. The difficulty is that even stringent standards do not solve all of the economic problems. Firms will still be given pollution levels up to the standard for free. Indeed, all of the estimates in this study are based on an assumption of compliance with regulations. The focus is, however, on existing regulations, not on all regulations that will emerge as a consequence of the new Clean Air Act. As a result, the incentive of firms to enter the industry will be too great.<sup>10</sup> The appropriate economic solution to achieve an efficient outcome requires the use of some kind of system to augment regulations. The level of these fees will, however, be influenced by the stringency of current regulations -- a

complication not incorporated in the analysis. Continuing research under this project is exploring how the role of existing EPA standards can best be reconciled with the utilization of a full social cost energy pricing approach. It should, however, be emphasized that the results in this report do recognize that EPA regulations exist. In particular, compliance with existing regulatory standards serves as the principal reference point for analysis.

The nature of the full social cost pricing approach also must be refined before its ultimate implementation. Ideally, the tax should be on pollution, not on energy. The most obvious distinction that must be made is between anthracite and bituminous coal. However, generally there will be a need to reorganize differences in pollution associated with a particular energy source. One of the main purposes of an energy pollution-free system is to encourage innovation to reduce pollution, such as by introducing control equipment that will decrease pollution from a particular form of energy. Firms will have no such incentive if they are penalized based on the type of energy they use rather than on the damage that it generates. The ultimate objective is to establish fees for pollution not for energy use. The calculations in this paper present what such a fee structure would look like overall, but should not be regarded as providing a rationale for ignoring the level of damage associated with each energy source.

### 2.3. ENERGY SOURCES AND POLLUTANTS

Existing evidence on the costs associated with energy are most developed for various forms of petroleum (gasoline, diesel, aircraft fuel, heating oil, and natural gas), wood, and coal.” Excluded from this listing are three energy sources for which the environmental damages may be negligible. Wind and solar power generate virtually no adverse environmental effects, and the water pollution and air pollution damages associated with geothermal power are believed to be minimal.

Another energy source that we will not examine is nuclear power. Unfortunately, there is no comparable governmental study of nuclear hazards that enables us to include the associated nuclear risks in our analysis. In contrast, pollution emissions levels are observable, and with the aid of health benefit assessments, it is possible to make judgments pertaining to the likely impacts of pollution from coal, wood, and petroleum-based fuels.

Assessment of the costs of nuclear power is a quite different enterprise.” Major reactor failures are a rare event. How, for example, should we incorporate the Chernobyl experience in risk assessments for the U.S. nuclear industry? We observe signals of likely hazards -- faulty safety practices, minor mishaps, and near disasters -- but ultimately the risk assessment for nuclear power hinges on subjective assessments of human and engineering failures. Some observers claim that the risks have been overblown, whereas others view nuclear power as a serious threat. We do not view these uncertainties as insurmountable, but to date there have been no definitive assessments of the risks of nuclear power. In the



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absence of governmental risk assessment for nuclear power or a comparable definitive analysis, nuclear power will be excluded from consideration.

The social cost results below should not provide a relative subsidy to nuclear power simply by default. Before any environmental cost fee system is implemented, there should be a comparably vigorous assessment of the expected externality costs associated with nuclear energy.

Each of the columns in Table 2.1 list the different energy sources that will be the subject of the assessment. For each energy source, seven different components of external costs were considered. The importance of these categories differs by energy source. For gasoline, the most detrimental externalities are for particulate, in large part because EPA regulations have already greatly reduced the role of lead pollution from motor vehicles. Particulate are also an important category of pollution for diesel, aircraft fuel, and wood. For coal and heating oil, sulfur oxide mortality is of greatest import. Ozone is the most damaging pollutant linked to natural gas.

The externality costs associated with each pollutant are given both in terms of a contribution per unit of the fuel as well as a percentage of the 1986 retail price.<sup>13</sup> The year 1986 was selected to ensure the availability of the key data components. The estimates in Table 2.1 are based on the midpoints of the estimated EPA pollution benefit ranges. The degree of uncertainty in these estimates is explored below. These estimates also pertain to average benefit values over the entire range of remaining benefits. For the purpose of the analysis it was necessary to assume that marginal and average damage levels from pollution are equal since data are not available to permit estimation of the curvatrue of the relationships. As a consequence, these estimates may understate the marginal unit benefits of pollution reduction.

The role of the different pollutants varies by energy source. The remaining lead in gasoline imposes external costs on society that constitute roughly 1 percent of the retail price.” Particulate emissions are pertinent to all the energy sources listed in Table 2.1. With the exception of natural gas, every energy source generates substantial particulate emissions. Both motor fuels as well as stationary source fuel combustion are involved.<sup>15</sup> Particulate emissions impose costs on society equal to 9 percent of the price of gasoline, 23 percent of the price of diesel, 11 percent of the price of aircraft fuel, 6 percent of the price of heating oils, under 1 percent of the price of natural gas, 147 percent of the price of wood, and 25 of the price of coal.

The next two categories of externalities in Table 2.1 pertain to sulfur oxides. Emissions of sulfur dioxide and resulting sulfate particles from motor fuels and stationary source fuel combustion impose losses that can be best distinguished in terms of those that affect mortality and those that do not.<sup>16</sup> Although significant sulfur oxide costs are

Table 2.1

Unit Value of Benefits of Emission Reduction to Zero Following Compliance with Current Standards"

<b>Pollution Category</b>	<b>Gasoline \$ per gal (% of price)</b>	<b>Diesel \$ per gal (% of price)</b>	<b>Aircraft Fuel \$ per gal (% of price)</b>	<b>Heating Oils \$ per gal (% of price)</b>	<b>Natural Gas \$ per 1,000 ft<sup>3</sup> (% of price)</b>	<b>Wood \$ per short ton (% of price)</b>	<b>Coal \$ per short ton (% of price)</b>
<b>Lead in Gasoline</b>	0.0108 (1.16)						
<b>Particulates</b>	0.0831 (8.92)	0.2156 (22.94)	0.0679 (10.55)	0.0432 (6.23)	0.0181 (0.46)	91.0788 (147.43)	8.4069 (25.25)
<b>Sulfur Oxides Excluding SO<sub>4</sub> Mortality</b>	0.0005 (0.05)	0.0029 (0.31)	0.0003 (0.04)	0.0102 (1.48)	0.0001 (0.00)	0.1166 (0.04)	4.3005 (12.92)
<b>Sulfur Oxides SO<sub>4</sub> Mortality</b>	0.0169 (1.82)	0.1044 (11.10)	0.0091 (1.42)	0.3653 (53.09)	0.0026 (0.07)	0.9108 (1.48)	154.51 (464.00)
<b>Ozone</b>	0.0214 (2.30)	0.0176 (1.87)	0.0055 (0.86)	0.0021 (0.29)	0.0228 (0.58)	2.1076 (3.41)	1.0579 (3.18)
<b>Visibility</b>	0.0008 (0.09)	0.0051 (0.55)	0.0005 (0.07)	0.0178 (2.60)	0.0001 (0.00)	0.0425 (0.07)	7.54 (22.66)
<b>Air Toxics from Motor Vehicles</b>	0.0223 (2.40)	0.1281 (13.63)					

These estimates are based on midpoints of the estimated range of values.

associated with both diesel and heating oils, by far the greatest relative cost of sulfur oxide externalities are those associated with coal. Sulfide damages excluding mortality constitute 13 percent of the price of coal, and the mortality effects constitute 464 percent of the price of coal. Put somewhat differently, the midpoint estimates of the sulfur oxide mortality effects of coal are almost 5 times larger than the market price of coal. As will be indicated below, the level of these costs is also very uncertain.

The next category of externalities are those associated with reducing ambient ozone concentrations resulting from motor fuels and stationary source fuel combustion.” The costs of ozone pollution constitute 2 percent of the price for gasoline and diesel, under 1 percent of the price for aircraft fuel, heating oils, and natural gas, and 3 percent of the price for wood and coal. The visibility externalities are largely associated with reducing sulfur oxide emissions from coal-fired power plants.<sup>18</sup> These visibility costs constitute 23 percent of the price of coal.

The final environmental cost component in Table 2.1 consists of the quantities of potential cancer cases related to non-lead emissions from motor vehicles.<sup>19</sup> These air toxic effects constitute 2 percent of the price of gasoline and 14 percent of the price of diesel.

## 2.4. EXTERNALITIES AND NET TAXES

Ideally, the prices of these various energy sources should reflect the social costs they impose. To adjust for these costs one can impose an additional charge on the use of these energy sources. In effect, all usage of each energy type is treated as causing the same average amount of pollution. If this policy is implemental, some mechanism should be adopted to link the charge to pollution. It is emissions of pollutants, not energy usage, that should be discouraged, such an approach will also provide incentives for pollution-reducing innovations.

One might view these charges as being a user fee for the environmental resource that is not properly recognized in market transactions. To the extent that there are existing taxes imposed on energy sources, these would correct at least in part for the disparity between the private price and the social price of the energy source.

Table 2.2 summarizes the current net taxes paid by various energy sources as well as the external costs that are generated. In situations in which the taxes equal the external costs, no additional charges on the energy source are appropriate.

Current taxes on gasoline are 17 percent of the price, roughly the same as the externality cost. In the case of diesel fuel, the current net tax per gallon is 13 percent, whereas the externality cost per gallon is 50 percent. In the case of aircraft fuel, the current net tax per gallon is 16 percent of the price, and the externality cost is 13 percent. Existing

**Table 2.2**  
**Summary of Energy Externalities and Taxes**  
**Assuming Compliance with Existing Environmental**  
**Regulations**

	Current Tax per Unit 1986 <sup>a</sup>	Current Tax as a Percent of Price (1986)	Externality Cost Estimate as a Percent of Price (1986) <sup>b</sup>	Relative Carbon Tax <sup>c</sup>
Gasoline (gal)	0.15	16.60	16.74	27.89
Diesel Fuel (gal)	0.12	12.80	50.40	52.88
Aircraft Fuel (gal)	0.10	15.50	12.94	NA
Natural Gas (1000 cu. ft.)	0.25	6.40	1.11	1.00
Heating Oils (gal)	0.10	14.60	63.69	47.99
Wood (tons)	0.00	0.00	152.43	0.00
Coal (tons)	11.95	35.90	528.01	104.87

a. Excludes taxes designated for Federal Highway Trust Fund, Superfund Tax, and Black Lung Tax.

b. Based on midpoint environmental damage estimates in Table 1.

c. Based upon carbon emissions per unit fuel. Relative carbon tax values are normalized with natural gas equal to 1,

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tax levels are below the amount of the appropriate user fee in the case of diesel fuel, but there is no such discrepancy for gasoline and aircraft fuel.<sup>20</sup>

Heating oils represent a case similar to that of diesel fuel. The current tax level is 15 percent, whereas the environmental cost is 64 percent. Natural gas currently has taxes of 6 percent, whereas the environmental cost is 1 percent. Somewhat strikingly, the current tax levels for natural gas are in fact above the user fee level based on this analysis. Moreover, the environmental costs are very low in percentage terms.

Wood currently is not taxed, whereas the appropriate user fee for each short ton of wood is 152 percent of the price. Heat provided by wood stoves clearly is not a totally environmentally responsible solution to the energy crisis.

The case of coal is most dramatic. The current tax per ton of coal is 36 percent of the price, whereas the environmental costs are 529 percent of the price.

These taxes can be also put in different terms more closely linked to the current greenhouse debate. Advocates of policies to address greenhouse warming frequently propose that a carbon tax be implemented.<sup>21</sup> The externalities considered here can also be incorporated within the context of a carbon tax, but the level of the base carbon tax to account for the externalities other than greenhouse warming will not be uniform. The final column in Table 2.2 indicates how high the relative carbon tax on each fuel should be, where the level of the carbon tax has been normalized by setting the tax on natural gas equal to 1. The relative carbon tax for those gasoline sources for which estimates are available is much greater than it would be on natural gas, which is a comparatively clean energy source. The relative carbon tax levels range from 1 for natural gas to 28 for gasoline to 105 for coal. A uniform carbon tax is not an appropriate vehicle for addressing environmental damages other than global warming. One of the major advantages of our approach is that it adjusts for the substantial heterogeneity in environmental costs rather than relying on a simple carbon tax.

Irrespective of whether the tax is levied through a carbon tax or some other mechanism, the total price tag for the externalities will be quite high. Table 2.3 summarizes the total environmental costs associated with each energy source, assuming that there is no change in the quantity of energy used. There would, of course, be a substantial shifting away from energy sources whose relative price increased. The total tax amount is \$208 billion, which is about two-thirds of the \$281 billion projected budget deficit for fiscal year 1992.<sup>22</sup> Over two-thirds of the estimated energy tax amount is attributable to coal. Gasoline, heating oils, and wood would be taxed in the \$10-\$20 billion range, and coal would be \$149 billion.

Imposing externality charges of this magnitude is certainly a daunting prospect. A major source of the relative popularity of regulatory standards as compared with taxes is that

**Table 2.3**  
**Total Tax Revenue for Each Fuel Type\***

<b>Fuel Type</b>	<b>Total Tax Revenues (\$ billions)</b>	<b>Net Tax Revenues (\$ billions)</b>
<b>Gasoline</b>	<b>26.87</b>	<b>17.98</b>
<b>Diesel Fuel</b>	<b>5.00</b>	<b>2.38</b>
<b>Aircraft Fuel</b>	<b>1.71</b>	<b>1.71</b>
<b>Heating Oils</b>	<b>4.72</b>	<b>4.70</b>
<b>Natural Gas</b>	<b>4.11</b>	<b>4.11</b>
<b>Wood</b>	<b>NA</b>	<b>NA</b>
<b>Coal</b>	<b>10.17</b>	<b>9.61</b>
<b>TOTAL TAX</b>	<b>52.58</b>	<b>40.49</b>

**\*For midpoint of range**

**\*\*Based upon most recent estimated consumption**

**volumes. 1989 in most cases except wood, 1987. All figures in 1986 dollars.**

firms do not currently have to pay for these costs. In effect, the imposition of regulatory standards allows firms to have a level of pollution up to the standard for free.<sup>23</sup> Standards can be effective in promoting the efficient degree of pollution control for any particular energy source, but they will not provide the correct incentives for the modal choice among alternative sources of energy.

Suppose, for example, that there are two possible sources of energy. Source A is a highly polluting energy source for which it is very difficult to reduce pollution levels. Source B is a very clean energy source for which it is possible to virtually eliminate the pollution level at little cost. Setting efficient regulatory standards, which is to say those that equate the marginal benefits to society of additional pollution reduction with the marginal costs of controls, will lead to very minimal pollution reduction for energy Source A, but may lead to the elimination of pollution for Source B. In each case efficient controls would have been imposed for the energy source, but what remains is an immense uncompensated environmental cost imposed on society for energy Source A. Notwithstanding these externalities, society perhaps should continue to use Source A. However, unless the price that consumers pay for this energy source reflects the remaining environmental costs that are generated, the price mechanism will not provide consumers with the appropriate incentive for making the appropriate energy choice.

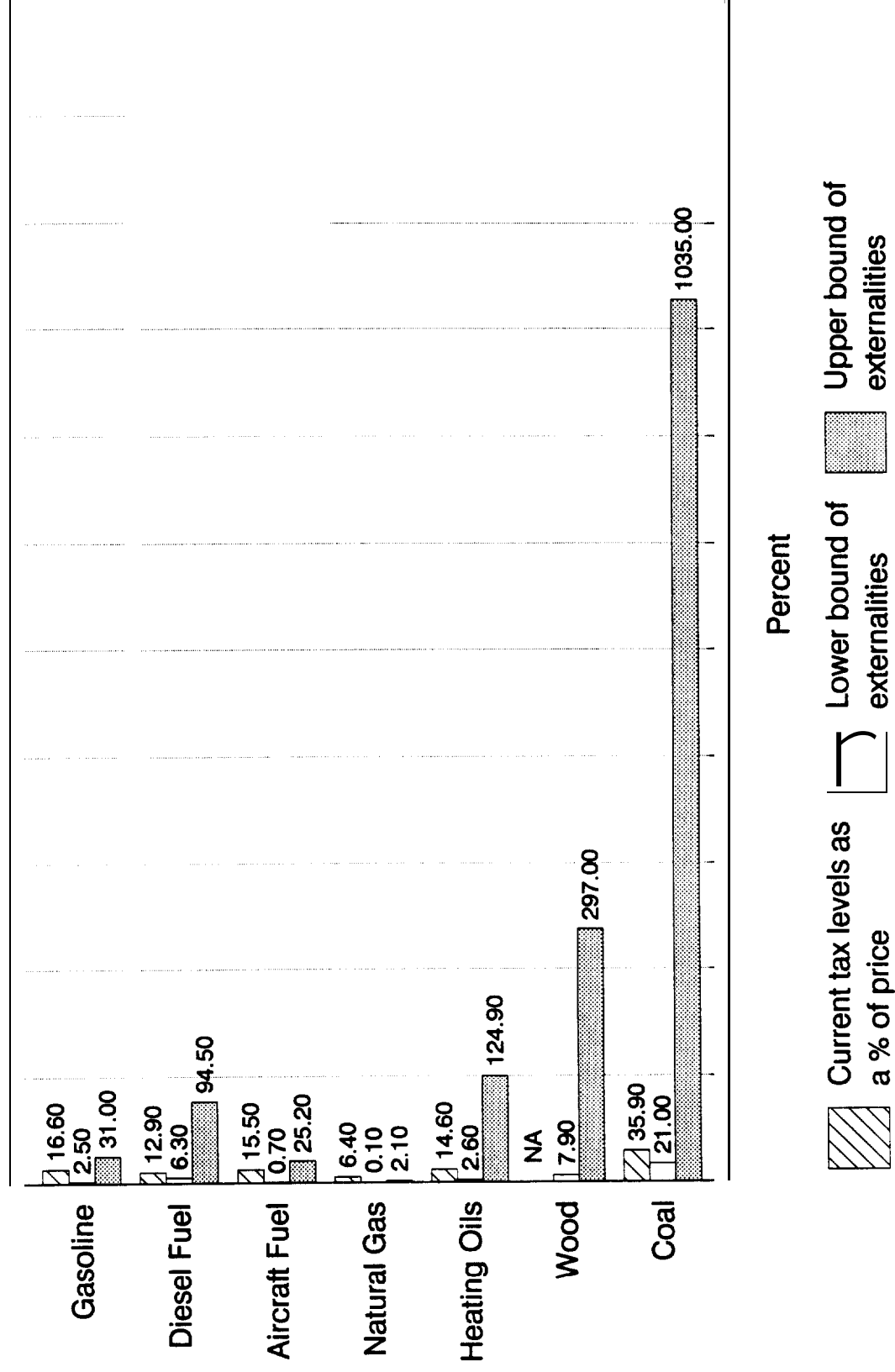
## 2.5. THE RANGE OF UNCERTAINTY<sup>24</sup>

One reason for caution with respect to implementing such externality charges is that there remains considerable uncertainty in the ranges of the cost estimates. The pollution effect estimates are disputed by private industry officials as well as by many independent analysts. Moreover, there remains a substantial range of uncertainty implied by the governmental studies on which this analysis has been based. Most of those analyses served as the economic framework underlying the justification of government regulations and, as a consequence, were the result of substantial research effort. The range of uncertainty that remains reflects, at least in part, the current imprecision of our scientific knowledge that may be costly to reduce.

Instead of focusing on environmental costs based on the midpoints of government analyses, Figure 2.1 indicates the current tax amounts, and the lower and upper bounds on the appropriate environmental cost surcharge. Gasoline has a modest range of uncertainty -- from 2.5 percent to 31.0 percent of its price. In contrast, the lower bound estimate for coal externalities is 21.0 percent, and the upper bound is 1,035.0 percent.

It is instructive to consider some of the sources of these uncertainties. In the case of gasoline, the principal uncertainty is the societal cost of particulate emissions, for which the estimates range from 0.5-17.4 percent of the price. Particulate costs are also the major uncertainty for diesel (1.2-44.7 percent of the price), aircraft fuel (0.5 -20.6 percent of the

Figure 2.1  
Taxes and Air Pollution Externalities as a  
Percent of Fuel Price



Source: W. Kip Viscusi and Wesley A. Magat, "Interim Draft Report on Efficient Energy Pricing," Report to U.S. EPA, September 1991.



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price), and wood (7.5 -287.4 percent of the price). The sulfur oxide mortality effect range is the greatest for two energy sources -- heating oils (0.0-106.2 percent of the price) and coal (0.0-928.0 percent of the price). Although one can make judgments regarding the appropriate estimate within these ranges, such as our reliance on the midpoints, the range of uncertainty signals the potential benefits of improving the informational base underlying full social cost energy pricing. The extent of uncertainty, our ability to resolve the uncertainty, the cost of resolving the uncertainty, and the benefits to the design of the energy pricing system all affect the desirability of acquiring this information.

Unless there is no potential for information acquisition, these results imply that adopting the “no regrets” social cost pricing approach may also involve substantial regret as well. The presence of uncertainty need not paralyze policy development since taking no action may be costly as well. It does suggest, however, that policies of information acquisition and refinement of these environmental damage estimates should be a high priority for additional research.

## **2.6. CONCLUSION**

Reverting to an environmental strategy of “no regrets” that abstracts from the risks of global warming does not completely simplify the policy task. The remaining uncertainties involved are currently substantial, though they can potentially be reduced through additional scientific and economic research. There is a particular need for further knowledge of the nature of the relationship between the external costs on society and additional reductions in pollution. In addition, some of the most uncertain high stakes externality components, such as sulfur oxide mortality, merit detailed scrutiny so as to narrow the range of uncertainty.

Shifting the focus from greenhouse warming to more short-term air pollution problems also does not eliminate the need for bearing enormous economic costs. The levels of the environmental damages involved are substantial -- possibly on the order of hundreds of billions of dollars annually. Non-environmental costs may be significant as well. A society that is reluctant to incur an extra nickel/gallon tax on gasoline is unlikely to accept a substantial increase in its energy bill, particularly in the short run.

The difficulty is that there is no explicit market transaction that makes clear the immense implicit price for energy pollution that society is now paying. Adverse health effects, such as mortality, are diffuse. Many of these impacts occur with a long time lag, and their incidence cannot easily be linked to particular energy sources. As a result, their magnitude is widely debated. The certainty of an immediate expenditure for energy taxes consequently will tend to loom larger than the dimly understood prospects associated with environmental damages. These would be viewed more favorably if the government were to substitute energy taxes for other taxes that produce economic distortions, such as income

taxes.

Even if society does not adopt a full social cost pricing system for energy, analyzing what the prices should be from an efficiency standpoint provides an illuminating framework for an analysis. Chief among the conclusions of this study is that the prices of the energy sources that seem most out of line with their environmental damage are coal and wood. Natural gas is a comparatively clean energy source that is currently taxed more than is warranted given the costs that its use imposes on society. Moreover, the almost exclusive obsession of the popular press and much government regulation with private motor vehicles appears to be misplaced. Gasoline pays its own way in the sense that the current gasoline tax equals the environmental damage imposed. Perhaps because of these efforts, the gap between the environmental costs resulting from gasoline and the taxes already imposed is much less than for energy sources such as diesel fuel and heating oils. Moreover, all of those adverse effects are dwarfed by the enormous, but highly uncertain environmental costs associated with coal.

Pursuit of a “no regrets” policy of full social cost energy pricing raises the same class of concerns as do proposals to address climate change, but to a lesser degree. The stakes are immense, the uncertainties are considerable, and the possibility of regret over controlling pollution by more than will prove to have been warranted is quite real. These parallels suggest that this entire policy area involves intrinsic uncertainties. Ultimately, decisions will have to be made without clear-cut guarantees regarding their effects. At the same time, these uncertainties suggest that the value to society of scientific and economic research that improves the environmental information base may be considerable.

## NOTES

1. There remains a debate regarding the implications of climate change for greenhouse warming. Some areas may be affected differently by climate change. In addition, some researchers hypothesize that there may be global cooling. The emphasis of this paper will be on greenhouse warming, recognizing that there are diverse scientific views. See the National Academy of Sciences, Policy Implications of Greenhouse Warming (Washington: National Academy of Sciences, 1991). Some states share these concerns. See the New York State Energy Office, Draft New York State Energy Plan, Executive Summary, July 1991.

2. Others have labeled this the “bootstrap” approach. See Stephen H. Schneider, Global Warming: Are We Entering the Greenhouse Century? (San Francisco: Sierra Club Books, 1989).

3. Our analysis of this “no regrets” approach does not imply an endorsement of it. If the effects of current actions are irreversible, waiting for uncertainties to be resolved may impose considerable costs.

4. National Academy of Sciences (1991), p. 73.

5. Some other omitted cost categories are those related to the following: urban vehicle congestion due to non-pricing of road use during peak hours; overbuilding (from an economic perspective) of housing (and hence overuse of heating and cooling) due to the home mortgage deduction; possible overuse of energy due to the inclusion of costs for energy-using utilities in the rents charged for many apartments; possible overuse of highways to haul freight in heavy trucks that may not pay the full cost of the damages they cause to the highways; and possible adverse effects of dependency on foreign oil on U.S. trade policy. An issue arises as to what extent some of these externalities should be attributed to the general activity or the energy source. The analysis also excludes total life cycle environmental costs and only examines costs associated with energy use. Total costs for the fuel cycle also are likely to be greatest for coal.

6. The main building blocks for our assessment are past U.S. Environmental Protection Agency (EPA) studies of the economic damages from environmental pollutants resulting from fossil fuel use that the agency prepares as part of its major regulatory initiatives. Although these estimates can clearly be debated and possibly refined, they have received substantial internal and public review since they provide the analytical foundation for U.S. regulatory policies.

7. It should be noted that the user fees should be regarded as only an initial approximation to such optimal fee levels. The theoretically correct user fee amount is based on a complex set of economic influences beyond the degree of refinement possible with available data. See Carlton and Loury (1980).

8. These studies in turn have sometimes relied on the academic literature. The upper bound of the damage estimates is based on Lave and Seskin (1978). The energy cost estimates are based on Evans (1984).
9. See Nichols and Zeckhauser (1986), Lave (1982), and Zeckhauser and Viscusi (1990).
10. Thus, we will have achieved short-run efficiency, not long-run efficiency.
11. See Hall (1990), Schelling (1983), and Schelling (1991).
12. See Hall (1990) for a review of the literature on these effects.
13. These calculations also assume that compliance with existing EPA standards will achieve a 25 percent reduction in current pollution levels. To ensure comparability, the analysis uses 1986 as the reference year.
14. These estimates were based on information from the U.S. EPA, Office of Policy Analysis, Costs and Benefits of Reducing Lead in Gasoline. Final RIA, February 1985, chapter VIII.
15. The underlying externality estimates are based on information from the U.S. EPA, Strategies and Air Standards Division, Regulatory Impact Analysis of the NAAQS for PM. Second Addendum, December 1986.
16. The basis for these estimates is the U.S. EPA, Office of Air and Radiation, Regulatory Impact Analysis of the NAAQS for Sulphur Oxides (Sulphur Dioxide), Draft Report, March 1988, Executive Summary, Appendix B.
17. Resources for the Future, "The Health and Agricultural Benefits of Reduction in Ambient Ozone in the United States," December 1988, chapters 3 and 5.
18. National Acid Precipitation Program, Integrated Assessment Question One Economics, June 11, 1990.
19. U.S. EPA, Office of Mobile Sources, Air Toxics Emissions From Motor Vehicles, September 1987, Executive Summary.
20. This tax would be even larger if we knew the externalities for NO<sub>x</sub>.
21. See Nordhaus and Yohe (1983), Poterba (1991), and Nordhaus (1991).
22. See Council of Economic Advisors (1991), p. 375.
23. See Crandall (1983).

24. Uncertainty is an inherent component in other risk regulation contexts as well. See Wilson and Crouch (1991).

## PREFACE TO THE APPENDICES TO PART II

At this time, the full social cost pricing study considers only air pollutants resulting from combustion of fuels. The scope of the study could be expanded in two ways, one, by adding other pollutants and pollution endpoints of concern, and two, by including other relevant points in the fuel cycle (e.g. wastes created from the exploration, development and production of fuels). We have considered several such extensions of the study's scope, but in most cases we were unable to identify quantitative assessments of benefits sufficient in detail to derive unit benefits estimates.

Many different approaches have been used to investigate optimal energy taxes. This study follows a direct method of estimating the potential benefits from fuel consumption at current emissions levels and fuel use rates. Benefits of other levels of emissions are then calculated assuming a linear no threshold model. One study incorporating a similar approach was recently reported by the New York State Energy Office. The methodology incorporated in that study is briefly described in appendix 2.

Appendix 2.1 is a detailed discussion of the sources of information used in this report and the assumptions and calculations used to derive the benefits estimates. It is the intent of this discussion that a researcher could duplicate the estimates in this report by following the same steps as described in the appendix. Appendix 2.2 is a brief review of the method followed in the recent New York State study. Appendix 3.1 draws upon the unit benefit estimates generated here to compare a number of different approaches for implementing social cost energy pricing. These results are presented in tabular form for the following implementation approaches, a consumption tax, a production/import tax, a carbon tax to recover air pollution externalities, a coal output tax, an electricity tax, a gasoline and diesel fuel tax, and a comprehensive emissions fee system. A number of different implementation and institutional issues are raised for each approach.

APPENDIX 2.1  
SUMMARY OF BENEFITS DATA

## 1. INTRODUCTION AND SOURCE MATERIAL

The focus of this report is to catalogue the benefits available from elimination of air pollutants resulting from the combustion of fuels and to calculate the optimal taxes to account for energy-related pollution. Throughout this research effort, the benefits associated with fuel sources were drawn from existing government (or government sponsored) benefit assessments typically written for a specific pollutant, for example, sulfur dioxide or lead in gasoline. Several of these studies were conducted by the U.S. EPA's Office of Air and Radiation in the review of National Ambient Air Quality Standards (NAAQS). The benefits study cited for lead in gasoline was performed by the EPA's Office of Policy Analysis. Other studies were performed by the Office of Mobile Sources, also of the EPA, and by the National Acid Precipitation Assessment Program (NAPAP). One cited study was performed by a nonprofit research and consulting firm, Resources for the Future, under contract to the Office of Technology Assessment (OTA).

Because of the diverse set of benefits studies that we have drawn from, benefits values were often reported for different time frames using different accounting conventions. The numbers drawn from each study have been normalized to the annual dollar value of benefits in 1986 constant dollars for calendar year 1986. The year 1986 was chosen strictly for computational convenience. The specific steps taken to normalize the benefits from each study are reported in detail below.

Table A2.1.1 lists the normalized benefits drawn from each government assessment. Source documents typically reported total benefits for all sources of a particular pollutant. This research report, however, focusses only on pollutants resulting from fuel-related sources. Many pollutant sources in the source documents are nonfuel-related. For example, particulate pollution may be the result of dust from dirt roads, forest fires and volcanos. Ozone pollution may result from evaporation of solvents in paints. Therefore, benefits data were adjusted to account for fuel-related sources of pollution, only.

The most desirable method of adjusting the benefits data for pollution sources would be to first determine the background concentration of each pollutant and then to determine the marginal contribution to ambient concentration resulting from fuel sources. Unfortunately, this approach is precluded by the lack of detailed air quality data. As a second best measure, emissions to the environment will be used as a proxy for environmental quality data.

The EPA annually publishes air pollutant emissions estimates in the National Air Pollutant Emission Estimates series. Emissions estimates from this source were used to relate the 1986 normalized health and environmental benefits to fuel-related pollution sources. The EPA reports emissions for each of the following pollutants, lead, particulate, sulfur oxides ( $\text{SO}_x$ ), nitrogen oxides ( $\text{NO}_x$ ), volatile organic compounds (VOC's), and carbon monoxide (CO) for each of the following source categories, transportation, stationary source fuel combustion, industrial processes, solid waste disposal, and miscellaneous.



No comprehensive benefits data were identified for the pollutants NO<sub>x</sub> and carbon monoxide; therefore, any health and environmental benefits resulting from reduction of these two pollutants are not captured in this study. To the extent that such benefits exist, the documented externalities may be underestimated because NO<sub>x</sub> and CO effects are not incorporated.

Another source of potential underestimation may occur because benefits estimates drawn from the source documents were scaled downward to account for benefits which could not be linked with a specific fuel-related emissions source. The EPA emissions data delineate emissions into two fuel-related categories, namely, transportation and stationary source fuel combustion. For the transportation category, the EPA emissions estimates are further detailed into the following subcategories, highway, diesel, aircraft, railroads, vessels, farm machinery, construction machinery, industrial machinery, and other. As will be explained in more detail below, only the first three categories relate to a specific fuel source (e.g. gasoline, diesel fuel, or aircraft fuel). Because of the difficulty of assigning the other emission categories to specific fuel sources, benefits estimates were scaled downward to exclude these source subcategories. Table A2.1.1 lists the proportion of benefits identified in the government assessments which have been allocated to transportation and fuel combustion based upon this EPA data. The net benefits used in the remainder of this research report are found in the final two columns of Table A2.1.1.

Throughout this report, ambient air quality is proxied by emissions of each pollutant of concern. Table A2. 1.2 lists the emissions of each pollutant in 1986, and calculates the net benefits (from Table A2.1.1) of existing regulations measured per unit of emissions. Clearly, the lead in gasoline regulation yields several orders of magnitude higher benefits per gram emissions than other regulations. Relative comparisons among the other pollutants should be made with caution, however. These specific figures are subject to the inadequacies/assumptions of the source materials such as choices of categories of benefits to include in each benefits assessment.

Another way to evaluate the data is by comparing benefits across fuel sources. Much of the remainder of this discussion focusses on fuel source comparisons. Table A2.1.3 lists the net benefits from Table A2.1.1, but the benefits are allocated over fuel sources. Clearly, the lead in gasoline regulations have generated significant benefits from gasoline. But looking at the upper bound estimates, it appears that the greatest source of potential benefits is from coal consumption. When looking at the benefits measured in BTU-equivalents across fuel sources, the greatest benefits are again from coal consumption, while most petroleum-derived products have similar benefits when measured in BTUS [BTU conversion factors drawn from the "Monthly Energy Review," January, 1987]. Throughout the projections made later in this report, this pattern will remain. The greatest potential to capture future benefits appears to be from the consumption of coal.

In the remainder of this research report, the net benefits identified in Table A2.1.1 are used to calculate benefits per unit of each fuel used in 1986 (i.e. dollar value of benefits per gallon of gasoline consumed in 1986). For example, the total benefits allocated to gasoline (based upon the proportion of emissions in 1986 from gasoline sources) are divided by the consumption of gasoline in 1986 to yield benefits per gallon. These unit benefits can be thought of as the unit benefits of strict compliance with current standards/regulations.

For computational convenience, unit benefits are assumed to be constant over time and constant for the level of emissions. This second assumption is equivalent to assuming that the health and environmental effects of each pollutant are linear with respect to air quality (proxied by emissions).

Assuming that unit benefits are constant, the unit benefits are used to extrapolate to the potential benefits from reducing emissions from identifiable fuel-related sources to zero. The unit benefit estimates and the projections to zero are found in Table A2.1.4 and Tables A2.1.6 through Table A2.1.10. The calculation of unit benefits and the method for projecting to zero are discussed in more detail below.

## 2. SOURCES OF UNCERTAINTY

Two types of uncertainty enter into the analysis. The first type is evident in Table A2.1.1 by ranges over which benefits are stated. The ranges reflect uncertainty in the source documents' calculation of benefits, and in some cases, 'the uncertainty may be extremely large--as in the range of benefits for  $SO_4$  mortality. The second type of uncertainty arises from the assumptions and limitations of this analysis and the data upon which the analysis is based.

For each pollutant listed in Table A2.1.1, benefits are displayed in ranges resulting from uncertainties in the benefits assessments. For lead in gasoline, the actual benefits of the regulation depend upon automobile owners' compliance with regulations requiring use of unleaded fuel. If cars are misfueled, by adding leaded fuel, the emissions systems may be impaired. The benefits range, therefore, reflects two different assumptions, no misfueling (upper bound) and partial misfueling (lower bound).

EPA's estimate of the benefits of controlling particulate incorporates uncertainty as to the extent of the health and environmental effects of particulate pollution and uncertainty regarding the economic valuations of health and environmental effects. The benefits analysis calculated benefits for a number of different scenarios reflecting underlying uncertainty in the health and environmental effects of particulate exposure. For this analysis, two scenarios were chosen as upper bound and lower bound benefits estimates based upon EPA's assertion that the two scenarios were most inclusive of the range of health and environmental effects without double-counting. In addition to the uncertainty over the precise health and environmental effects of particulate exposure, EPA's benefit

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range is due in part to the valuation assigned to mortality risk. Each case was assigned a value from \$430,000 to \$7,460,000.

In EPA's benefits analysis for sulfur dioxide, uncertainty is introduced by the air quality modelling procedures and by the economic valuations assigned health and environmental effects.

For mortality related to  $\text{SO}_4$ , the benefits range in Table A2.1.1 is significantly wider than the ranges for other pollutants. This range reflects the divergence of opinion in the scientific community regarding the mortality risk from exposure to  $\text{SO}_4$  as well as a broad valuation for reduction in incremental mortality risks. EPA's benefits estimates included all available risk estimates with no attempt made to select the most appropriate values. The broad range adopted by EPA was incorporated in this study; however, in addition to EPA's range, this study identifies an alternate upper bound estimate (referred to as the "modified upper bound") which may more accurately reflect the risks associated with  $\text{SO}_4$  exposure. The question of the risks associated with  $\text{SO}_4$  exposure is discussed in more detail below (section III.D).

The analysis of the benefits related to ozone includes uncertainty regarding both rate of incidence and valuation of symptoms.

The range of benefits related to visibility is the result of uncertainty in the economic valuation of visibility improvements.

The range of benefits associated with air toxics in motor vehicles results from uncertainty in the rate of incidence of several different air toxic pollutants.

The second type of uncertainty in this report results from limitations in source data and analysis method. While the intent of this exercise is to identify the optimal level of taxes on fuel sources to account for associated externalities, the optimal taxes can only be as comprehensive as the accounting of externalities. For example, no direct benefits from control of carbon monoxide or  $\text{NO}_x$  are included in this report. In the ozone analysis, impaired lung function is not valued. If these pollutants/effects are significant risks/endpoints in the population, they are not accounted for in the calculation of optimal energy taxes.

A second source of uncertainty is regional variation reflected--or not reflected--in the results. Some adverse health or environmental endpoints may be of concern only in some regions of the country. However, due to data and methodological limitations, such variations are not captured in this analysis. The EPA regulatory analyses that provided the foundation of our study are national in scope. Emissions data are a critical element in the unit benefit calculations described in detail below, but fuel consumption and pollutant emissions data are not available on a regional basis. Therefore, this analysis assumes that emissions are

distributed evenly throughout the country. This assumption may lead to some oversimplified results.

Another source of uncertainty is the true risk of exposure to different pollutants as ambient loadings of those pollutants change. Is the risk of an incremental exposure at high levels of ambient concentration equal to the risk of an incremental exposure at low levels of ambient concentration? In this analysis, unit benefits of emission reductions calculated at a given ambient concentration are used to estimate the benefits of further emissions reductions beyond the initial ambient concentrations. If the adverse health and environmental effects of pollutant exposures are actually nonlinear or exhibit a threshold effect, then using unit benefit estimates may introduce inaccuracies.

In some sense, despite its wide application in the literature, the linear, no threshold model incorporated in this report is an arbitrary approach. Adopting some other model is precluded by the lack of scientific consensus of the underlying relationships between air quality and health/environmental effects, and between emissions and air quality. In a recent report [New York 1991], the New York State Energy Office proposes an alternative linear threshold model; however, this approach is similarly arbitrary without a scientific basis for the threshold chosen and the resulting relationship between emissions and health effects. The New York State study is briefly reviewed elsewhere in this appendix.

An additional uncertainty relates to the base year and the fuel mix observed in that year. The volume of coal consumed in 1986, 768 million short tons, is composed of some mix of different types of coal, for example "high sulfur" and "low sulfur." If the mix of coal types changes over time, perhaps as a result of compliance with Clean Air Act requirements, then the unit benefits calculated for the base year would not necessarily be representative of the true unit benefits in future years. This caveat could apply to any nonhomogeneous fuel source, especially coal and heating oils.

Many of these underlying uncertainties are discussed in more detail in other sections of this report, and other uncertainties are addressed where appropriate.

### 3. UNIT BENEFIT CALCULATIONS

This section presents a more detailed description of the benefit data for each pollutant and of the unit benefit estimation method. As mentioned above, unit benefits incorporate government estimates of benefits, and can be interpreted as the unit benefits of strict compliance with existing regulations/standards. Table A2.1.4 which details unit benefits by pollutant and fuel source can be considered the benefits of compliance with existing regulations.

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In Table A2.1.4, unit benefits are presented for the following pollutants, lead in gasoline, particulate (more specifically,  $PM_{10}$ ), sulfur oxides (excluding  $SO_4$  mortality),  $SO_4$  mortality, and ozone. The benefits are allocated over the following fuel sources, gasoline, diesel fuel, aircraft fuel, coal, heating fuel oil, natural gas, and wood. The allocation of benefits occurs as follows. Recall that emission data are available for several transportation fuel categories and several stationary fuel source categories. For each pollutant, the proportion of total emissions resulting from each fuel category was calculated. This figure is multiplied by the total benefits for that pollutant to yield the benefits allocated to each fuel. For example, from the EPA emissions data in the report, National Air Pollutant Emission Estimates 1940-1988, gasoline accounts for 11.22% of the emission of particulate in 1986. The net benefits due to particulate are \$31,193 million (upper bound estimate as adjusted in Table A2.1.1). The benefits allocated to gasoline are \$31,193 million multiplied by 0.1122. Unit benefits are then estimated by dividing this result by the volume of gasoline consumed in 1986. Table A2.1.4 contains estimated unit benefits for each fuel-pollutant combination as well as a comparison of the magnitude of unit benefits and the price of each fuel type.

The benefits data for each pollutant are outlined in more detail below. See particularly the section on particulate to find the specific citations for fuel consumption and price data.

### Lead in Gasoline

Benefits data were drawn from EPA's Costs and Benefits of Reducing Lead in Gasoline, final Regulatory Impact Analysis which was produced in 1985 to accompany regulations reducing lead in gasoline. The specific benefits estimates used in this report were drawn from Table VIII-7c (low bound with partial misfueling) and from Table VIII-7a (high bound with no misfueling).

Categories of Benefits Incorporated:

Children: Benefits to children from reduced lead exposure included savings in expenditures for medical treatment (for lead testing and blood chelation therapy) and savings in compensatory education for IQ loss. Other adverse effects of lead exposure, including, chronic health effects, prematurity, birth malformation, and neurological disorders were not quantified.

Adults: Benefits to adults included morbidity and mortality effects of lead exposure. Morbidity benefits were restricted to avoided medical costs and foregone earnings for hypertension, stroke, and myocardial infarction. Mortality benefits valued at one million per individual based on occupational risk premium studies. Note: benefits were estimated for white males ages 40-59, only, with the exception of hypertension with also included nonwhite males in this age group.

Fuel economy benefits: The change in gas formulation was estimated to reduce fuel consumption. The dollar value of fuel savings were included.

Auto maintenance benefits: The changes would also lead to savings in vehicle maintenance. Dollar value of savings for spark plugs, exhaust systems, and oil changes included.

Conventional Pollutants: The fuel economy benefits will also reduce the release of other pollutants (primarily ozone) associated with gasoline combustion. Related benefits to health, agricultural crops, ornamental plants, materials, and visibility are included.

#### Benefit Scenarios Used:

Three scenarios are incorporated in the RIA, assuming no misfueling, partial misfueling, and full misfueling (misfueling occurs when conventional lead gasoline is used instead of unleaded gasoline). The benefit range used in the draft report reflects the latter two scenarios.

#### Unit Benefit Calculations:

Benefits estimated for 1986 were used in all calculations. These numbers were inflated from 1983 (as reported in the RIA) to 1986 using the implicit price deflator. All benefits are assumed to result from consumption of gasoline. The upper and lower bounds on the benefits range were each divided by the number of gallons of gasoline consumed domestically in 1986 (source: Basic Petroleum Data Book, section VII Table 21, 9/89) to yield a unit benefit value in terms of dollars per gallon consumed. The percent of 1986 price calculation incorporated the weighted [for lead and unleaded and for gasoline grades] average retail price per gallon based upon data from "Monthly Energy Review," 7/90, Table 9.4, from the Energy Information Administration.

#### Particulates

Benefits data were drawn from EPA's Regulatory Impact Analysis of the National Ambient Air Quality Standards for Particulate Matter 2nd addendum, December, 1986, Table III.C.1. [low bound] and Table III.C.2 [upper bound]. This analysis was completed to accompany the most recent revision the National Ambient Air Quality Standard (NAAQS) for particulate.

#### Categories of Benefits Incorporated:

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Mortality Incorporated a range of benefit from \$0.43 to \$7.46 per reduction of 1 X 10<sup>-6</sup> in mortality risk.

Morbidity: Valued lost workdays, reduced activity days, and direct medical expenditures from chronic respiratory disease. Lost work days were valued at the average daily wage, and reduced activity days were valued at one-half the daily wage.

Soiling: Estimated benefits from cleaning and well-being of reduced household soiling. Excluded soiling and materials damage in commercial, institutional, and government sectors.

### Benefit Scenarios Used:

EPA's estimates are based upon an extensive literature review of the adverse effects of particulate. The many studies reviewed each utilized different assumptions about the types of particles of concern, the exposed population, etc. EPA organized these results into six alternative standards (some more and some less strict than the current standard) and six aggregation methods. This report incorporates the estimates for strict adherence to the current standard (PM<sub>10</sub> at 50, annual and 150 24-hour) and for aggregation scenarios C and D which were judged by the EPA as most inclusive without double-counting.

### Unit Benefit Calculations:

EPA reported benefits as 1983 discounted present value in 1984 dollars at a 10 percent discount rate. The benefit flow was for the seven years from 1989 through 1995. For the draft report, total benefits were converted to typical year values for 1989 through 1995 in 1986 dollars.

Typical year benefits were allocated over fuel sources (including gasoline, diesel, aircraft fuel, heating fuel oil, natural gas, coal, and wood) based upon the proportion of emissions from each source. EPA has published emissions data for the NAAQS pollutants for 1940 through 1988 in the publication National Air Pollutant Emission Estimates 1940-1988. Emissions are reported for the following categories, transportation, stationary source fuel combustion, industrial processes, solid waste disposal and miscellaneous. Emissions from transportation are further detailed for gasoline powered highway vehicles, diesel powered highway vehicles, aircraft railroads vessels, farm, industrial, and commercial machinery, and other. Emissions from stationary fuel combustion are broken down into coal, fuel oil, natural gas, wood, and other. Total emissions combining the transportation and fuel combustion categories were allocated to fuel-related categories based upon the reported emissions for 1988. Note that in some cases, for example VOCS, a large portion of the emissions result

from activities other than fuel combustion. The benefits values drawn from existing reports were adjusted to reflect nonfuel emission sources. In addition, some benefits related to fuel combustion were excluded due to the difficulty in identifying the appropriate fuel source. The transportation categories: vessels, farm machinery, industrial machinery, commercial machinery, and other were excluded from our analysis because the actual fuel source for the emissions is not identified. The proportion of benefits uncounted due to these omissions is listed in Table A2.1.1.

After allocating the benefits over each fuel source based upon the emissions from that source, unit values (e.g. benefits per gallon) were calculated using consumption data from 1986. Consumption values for gasoline, diesel, aircraft fuel, and natural gas were drawn from the Basic Petroleum Data Book (BPDB) [gasoline, Table 21 section VII; diesel, Table 10a, section VII; aircraft fuel, Table 21 section VII; natural gas, Table 5a section XIII]. Consumption of heating fuel oils was estimated by summing residual and distillate fuels designated for the following uses, heating oils, industrial use, oil company fuel, and electric utilities [Basic Petroleum Data Book, Tables 10a and 12a, section VII]. Coal (net of coal used for coke plants) and wood consumption figures were drawn from the Annual Energy Review, 1987, from the Energy Information Administration, Tables 76 and 95, respectively. Wood consumption is for 1984.

The sources of price data are as follows: gasoline from the Energy Information Administration's (EIA) "Monthly Energy Review," Table 9.4, 7/90. Diesel fuel was drawn from the International Energy Annual, 1986, from the EIA, Table 17. The price of aircraft fuel is a weighted average based upon prices (excluding taxes) reported in the "Monthly Energy Review," Table 9.7 for aviation gas and kerosene-based jet fuel. The prices were weighted by the consumption volume for each found in the EIA's State Energy Data Report: Consumption estimates 1960-1986, Table 12. As this yielded a tax-free price, the unit tax on aircraft fuel identified in this report was added to the weighted price. The price of heating fuel oil is an average--weighted by the volumes of residual fuel oil (assumed to be equivalent to heavy oil) and distillate fuel oil (assumed equivalent to light oil)--of the reported price of No. 2 home heating oil from the Annual Energy Review, 1987, Table 65, and the price discount between residual fuel oil and No. 2 fuel oil found in the Monthly Energy Review, Tables 9.7 and 9.5. The BPDB provided the price of natural gas in Table 13, section VI. The price of coal, delivered at electric utility power plants, CIF (i.e. cost, insurance and freight) was drawn from the Annual Energy Review, 1987, Table 81. The price per ton of wood was estimated from information in the Regulatory Impact Analysis: Residential Wood Heater New Source Performance Standard conducted by the EPA in 1986. The report lists regional prices of wood sold by the cord at the retail level. These regional prices were weighted by 1986 regional population to yield a national average. This national average was discounted by 25



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percent, as suggested by the EPA analysis, to account for consumers who pay less than retail prices. Finally, the adjusted price per cord was converted to price per short ton based on the conversion factor found in "Monthly Energy Review," Table A1, January 1990. The values used for consumption and price are listed in Table A2.1.5.

### Sulfur Oxides (excluding SO<sub>4</sub> mortality)

Benefits data were drawn from EPA's 1988 Regulatory Impact Analysis on the National Ambient Air Quality Standards for Sulfur Oxides, Table 7 [for strict interpretation of current standards]. Benefits are estimated for 31 Eastern states, only. SO<sub>4</sub> mortality benefits were drawn from Tables B.2 and B.3. Agricultural benefits are calculated for only three crops, soybeans, wheat, and oats. Some ancillary benefits reported under sulfur oxides are the result of reduced particulate emissions from compliance with the sulfur oxides standards.

#### Categories of Benefits Included:

**Mortality:** Benefits are attributed to the reduced short-term non-episodic exposure to sulfur dioxide. Each statistical case is valued at from \$420,000 to \$7.3 million.

**Morbidity:** Sulfur dioxide morbidity is estimated only for short-term exposure. Long-term exposure is not included due to uncertainties. The symptoms valued include wheezing, shortness of breath, nose and throat irritation, and coughing. Symptoms are valued at from zero to \$50 per hour reduced. Particulate benefits are valued as in the particulate section.

**Agricultural:** Benefits calculated for increased crop yield for soybeans, wheat, and oats resulting from lower sulfur dioxide exposure.

**Visibility:** Benefits from improved visibility from reduced SO<sub>4</sub> emissions are included based on contingent valuation studies in nine cities. Materials Damage/Soiling: Soiling benefits from particulate are included similarly to those discussed in the particulate section. Materials damage from sulfur dioxide is valued at from \$0.77 to \$6.89 per year per household within the applicable distance from power plants.

#### Unit Benefit Calculations:

As in the particulate section discussed above, EPA reported in 1983 the present value of benefits in 1984 dollars for reductions from 1990 through 2000 discounted at 10 percent. These benefits were converted to typical year values in 1986 dollars and allocated as detailed in the particulate section.

### *SO<sub>4</sub> Mortality*

As in the case of sulfur oxides, benefits data were drawn from EPA's 1988 Regulatory Impact Analysis on the National Ambient Air Quality Standards for Sulfur Oxides, from Tables B.2 and B.3. Mortality associated with exposure to SO<sub>4</sub> is quite controversial. EPA did not explicitly include these benefits in the RIA; however, in an appendix, estimates of SO<sub>4</sub> mortalities are presented. Due to the controversial nature of the benefits, EPA estimated the lower bound of the benefits range at zero cases. Reflecting this uncertainty, the tables include SO<sub>4</sub> mortality as a separate category from sulfur oxides.

In estimating the range of benefits associated with SO<sub>4</sub> mortality, EPA cited all the available studies as well as the opinion of two unnamed experts. The study upon which the upper bound is based, Chappie and Lave, 'The Health Effects of Air Pollution: a Reanalysis/' has been criticized on many fronts. In Evans et al., "Cross-Sectional Mortality Studies and Air Pollution Risk Assessment," the authors perform a comprehensive review of the literature on SO<sub>4</sub> risk including reexamining the data analyzed by Chappie and Lave. In particular they correct for the seemingly arbitrary inclusion of three measures of SO<sub>4</sub> by Chappie and Lave, and they run regressions with separate measures of particulate and SO<sub>4</sub>. By using measures of these two pollutants as regressors, Evans estimates should decouple the effects of particulate from the SO<sub>4</sub> risk estimates. The paper by Evans admits to potential multicollinearity and lack of significance of some important variables; nevertheless, this risk estimate may be more appropriate than that of Chappie and Lave.

Taking the above discussion into account, Table A2.1.6, presents the unit benefits estimates as in the previous Table A2.1.4, except that the upper bound reflects the Evans estimate rather than Chappie and Lave. The total benefits for this assumption were calculated by the EPA in the analysis referenced above. Throughout the rest of this research summary, this scenario will be referred to as the "modified upper bound."

One other aspect of the SO<sub>4</sub> mortality estimates is of note. EPA's emission estimates are listed as for all sulfur oxides. In the most part, the emissions are sulfur dioxide. Once in the atmosphere, sulfur dioxide may be transformed to SO<sub>4</sub>. It is assumed throughout this research report that there is a one-to-one relationship between the EPA's reported level of sulfur oxides and SO<sub>4</sub>. Therefore, unit benefit calculations for the pollution categories sulfur oxides and SO<sub>4</sub> mortality utilize the same emissions figures.

### *Ozone*

Benefits data were drawn from The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States by Alan Krupnick and Raymond Kopp in 1988 [page 3-21 for health benefits and Tables 5-3, 5-5, 5-9, 5-11 for agricultural benefits] prepared under contract to the Office of Technology Assessment. The Office of Technology

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Assessment (OTA) published a 1989 report Catching Our Breath which estimated the health and environmental effects of ambient ozone; however, most of the OTA estimates were based on Krupnick and Kopp. By adjusting the assumptions made by Krupnick and Kopp, OTA estimated a broader range of benefits, particularly for health effects.

### Categories of Benefits Incorporated:

**Morbidity:** Benefits estimated for reduced incidence in Metropolitan Statistical Areas (MSAs) of acute respiratory effects, acute non-respiratory (eye irritation), restricted activity days, and asthma attacks. Each effect was valued using willingness-to-pay criteria based on review of the available contingent valuation studies. Benefits not included in the valuations included chronic respiratory disease, premature aging of the lung, links to cancer, and other non-asthma respiratory diseases.

**Agricultural:** Benefits estimated as the net change in consumer and producer surplus for nine crops based on increased crop yield from lower ozone. Crops included peanuts, barley, sorghum, oats, alfalfa, soybeans, corn, wheat, and cotton. Agricultural benefits excluded were other crops, forests, and ornamental plants.

**Visibility, materials damage:** Not included.

### Benefit Scenario Used:

Krupnick and Kopp included a number of scenarios based upon the available data and data uncertainty. Benefits were estimated for a number of different levels of ambient ozone exposure. The level, rollback to 0.12 ppm, was incorporated in this report as that most closely associated with compliance with the current standard. Agricultural benefits were estimated using a broader range of ozone exposure levels. Because of the differences in ozone levels in the health and agricultural benefits estimates, some inaccuracy is introduced by summing the benefits.

### Allocation Over Sources:

The cause of tropospheric ozone pollution is a controversial issue. Ozone is caused by the interactions of different chemicals in the atmosphere, and the chemical pathways generating ozone may differ under varying conditions and in different regions of the country (for example, in urban vs. rural areas). VOCs are clearly one cause of ozone pollution, and nitrous oxides ( $\text{NO}_x$ ) is considered another cause under certain conditions. Therefore, the estimates in this report assume that VOCs account for 75 percent of ozone while  $\text{NO}_x$  accounts for the remaining 25 percent of ozone pollution. Benefits were allocated over fuel sources (as explained in the particulate

section) for the emissions of both VOCs and NO<sub>x</sub> and then weighted by 75% to 25% respectively.

#### 4. UNIT BENEFITS OF EMISSIONS REDUCTIONS TO ZERO

Using the unit benefit ratios discussed in Section III, projections of potential benefits for reducing emissions to zero from identifiable fuel-related sources are detailed in Tables A2.1.7 through A2.1.10.

Two new categories of benefits are introduced in these tables, benefits from visibility related to acid deposition and benefits from air toxics associated with motor vehicles. In both cases, the source documents estimate the total adverse health/environmental result of existing air quality/emissions. In effect, these estimates calculate the potential benefits of eliminating emissions altogether. Therefore, the benefits are classified in this report as potential benefits from reducing emissions to zero, and are included only in the tables summarizing projected benefits (as opposed to the tables summarizing the benefits of compliance with existing regulations). This section first discusses the benefits from these two sources, and then presents the method for projecting future benefits for the categories presented in section II.

##### *Visibility (related to acid deposition)*

Benefits data on visibility were drawn from the National Acid Precipitation Program (NAPAP) study. The Integrated Assessment of the NAPAP study, (Question 1: Economics, p.26) cites work by Chestnut and Rowe who developed a “consensus function” to examine visibility values across a number of studies. Using their approach, Chestnut and Rowe estimated that the benefits of visibility improvement from an average visual range of 30 kilometers (km) to 150 km fall in the range from \$3.2 to 12.8 billion annually. Thirty km is the approximate average visual range in the eastern United States, and 150 km is the approximate average visual range in the absence of air pollution. Therefore, the estimate by Chestnut and Rowe can serve as a proxy for the benefits associated with reduction of emissions of sulfur oxides (and associated visibility inhibiting pollutants like NO<sub>x</sub>).

##### Unit Benefit Calculations:

Visibility benefits were allocated to fuel sources based on sulfur oxides emissions. Although other pollutants such as NO<sub>x</sub> and PM contribute to visibility reduction, sulfur oxides are the primary pollutant of concern. Benefits have been allocated across emissions categories based on 1986 output levels. Allocating benefits across emission sources may understate the benefits associated with coal fired electric utilities, the largest single source of visibility degradation.

*Air Toxics from Motor Vehicles*

Benefits for this section were drawn from a report from the EPA's Office of Mobile Sources, Air Toxics Emissions From Motor Vehicles, September, 1987, Table S-1.

Categories of benefits included:

The report identifies carcinogens associated with motor vehicles. As several of the source categories are not products of fuel consumption, such categories were excluded from our analysis. The remaining categories include diesel particulate, formaldehyde, benzene gasoline vapors, butadiene, ethylene, gasoline PIC/POM and VOCS from motor vehicles. Benefits are reported as a range of cancer deaths from each source. For two sources, butadiene and ethylene, uncertainties in the actual health effects resulted in a lower bound of zero deaths. No morbidity benefits are included.

Allocation over sources:

The pollutants cited result from combustion of gasoline and/or diesel fuel. Benzene, gasoline vapors, and PIC/POM were allocated entirely to gasoline. Diesel particulate are allocated entirely to diesel fuel. The remaining categories were allocated over gasoline and diesel based upon the volume of each consumed in 1986, gasoline 85.57 percent and diesel 14.43 percent. Source: Basic Petroleum Data Book, Table 21 section VII and Table 10a section VII, respectively.

Mortality Valuation:

No dollar valuations were included in the EPA study. For this report, each case was valued at four million dollars.

*Lead in Gasoline*

Two data elements are necessary to extrapolate to the benefits of reducing emissions to zero. The first element was estimated in Section III (above), namely, the available benefits, in this case, denominated in dollars per unit of fuel consumed. The second element is the level of ambient concentration of the pollutant from which the reduction to zero will be estimated. As in Section III, emissions will be used as a proxy for ambient pollutant concentration.

In the case of lead in gasoline, EPA issued regulations in 1985. Roughly two years were required for complete implementation of the lead phasedown. Over those two years,

as the EPA documented in National Air Pollutant Emission Estimates 1940-1988, lead emissions from transportation fell 31.2 million metric tons, from 34.7 million metric tons in 1984 to only 3.5 million metric tons in 1986.

Two important assumptions are incorporated into the projections of the benefits of reducing lead emissions from gasoline to zero. First, it is assumed that unit benefits are constant over any level of emissions. In other words, the benefit of reducing emissions by one unit when emissions are high is the same as the benefit of reducing emissions by one unit when overall emissions are low. While this assumption may well be an oversimplification, no generally accepted data are available to create a better relationship. In addition, the assumption is consistent with the linear dose-response models used by the EPA in the source documents.

While the preceding assumption is generic to the method used to calculate projected benefits, a second assumption is specific to lead in gasoline. As emissions fell 31.2 million metric tons from 1984 to 1986, it is assumed in these calculations that one-half of the emission reduction occurred in 1985 and one-half in 1986, i.e. emissions fell 15.6 million metric tons each year.

The annual emission reduction resulting from the regulation and the total emission level remaining were used to create an emission ratio. When multiplied by the unit benefit of compliance with the regulations, the result is the unit benefit of reducing emissions to zero  $[(\$ \text{ benefit} / \text{fuel consumption}) * (\text{remaining emission} / \text{emission reduction})]$ . Perhaps more intuitively, the equation could be rearranged  $[((\$ \text{ benefit} / \text{emission reduction}) * \text{remaining emission}) / \text{fuel consumption}]$ . In either case, the equation extrapolates from the annual unit benefit of complying with existing regulations to the quantity of emissions remaining, thereby yielding the annual benefit per unit of fuel consumption of reducing emissions from fuel-related sources to zero in one year. The results of this calculation for gasoline are found in the first row of Tables A2.1.7 through A2.1.10. Projections of the unit benefits for the pollutants particulate, sulfur oxides, and ozone require additional assumptions--leading to the four different cases captured in Tables A2.1.7 through A2.1.10--and are explained below.

#### Particulate, Sulphur Oxides, and Ozone.

Recall from above, that two information elements are necessary to extrapolate to the benefits of reducing emissions from fuel-related sources to zero, benefits data and ambient air quality (here represented by remaining emissions). For the case of lead in gasoline, the benefits data were available from the EPA regulatory impact analysis, and the emissions data were available from retrospective estimates of emissions.

For particulates--and for sulfur oxides and ozone as well--retrospective emissions data are not available. In the case of particulate and sulfur oxides, the EPA source documents estimate benefits of future emissions reductions. In the case of ozone, the source document predicts benefits if compliance with existing standards could be achieved. Because of the limitations of these analyses, we cannot peer into the records of pollutant emissions, rather some estimate of the emissions reductions which will/would result from compliance with the regulations must be made. A review of the background documents used by the EPA for the regulatory impact analyses yields little guidance on the air quality improvements or emissions reductions which would be associated with the regulations. Based primarily on an a priori judgement of what maybe reasonable, two initial cases have been used in these calculations. First, it is assumed that the existing regulations for particulate, sulfur oxides, and ozone will result in a 25% reduction in emissions in the year that the regulations are implemented (or in the case of ozone, in the year that compliance is achieved). It is secondly assumed, that there will be a 10% reduction in emissions.

Unlike the case for lead in gasoline where gasoline was the only fuel of concern, the calculation of projected benefits for these pollutants must occur on a fuel-by-fuel basis. Incorporating the unit benefit estimate for a particular pollutant and fuel combination, the calculation may be as follows  $[(\$ \text{ benefits} / \text{fuel consumption}) * (75\% \text{ emission remaining} / 25\% \text{ emission reduction})]$ . This calculation is repeated for each pollutant and each fuel combination using baseline emissions estimates from the most recent year available, 1988. The results are summarized in Table A2.1.7 for the case assuming a 25% emissions reduction in the first year following implementation of the regulation. Table A2. 1.8 summarizes the results assuming a 10% emissions reduction. Tables A2.1.9 and A2.1.10 repeat the same estimates incorporating the modified upper bound estimate for SO<sub>4</sub> mortality.

As discussed in section 11 (above), projections of benefits beyond the base year introduces uncertainty due to the possibility of changing fuel qualities. If the mix of different types of coal or heating oils change over time, then the unit benefit values based on the fuel mix in 1986 may not represent the true benefits of the fuel source in some other year.

## **5. PROJECTED BENEFITS OF SELECTED CLEAN AIR ACT' AMENDMENTS EMISSIONS REDUCTIONS TARGETS**

We have not attempted to conduct a comprehensive assessment of the benefits associated with the recent Clean Air Act Amendments. However, as a number of emissions reductions targets have been discussed widely, the unit benefits estimates from Section 11 have been applied to these targets. The resulting rough estimates of the benefits of the emissions targets are summarized in Table A2.1.11.

The estimates in Table A2.1.11 assume that sulfur dioxide emissions will be reduced by 10 million tons annually. Projected benefits of the 10 million ton target were calculated by applying unit benefit values--discussed in Section III. For sulfur dioxide, benefits were calculated for the following categories,  $\text{SO}_x$  morbidity,  $\text{SO}_4$  mortality, and visibility. The emissions reductions are anticipated at electric utilities, only; therefore, benefits were calculated for coal and heating fuel oil in proportion to their consumption by electricity utilities.

Anticipated reductions in VOCs were used to estimate the potential benefits associated with ozone reduction. An annual target of 10 million tons of VOC emission reduction was assumed. It was further assumed for this estimate that VOCs account for 100 percent of ozone formation. Benefits were allocated over all fuel sources.

## 6. SUMMARY OF ENERGY-RELATED TAX DATA AND TAX ALLOCATIONS

This section summarizes information collected to determine the average unit tax on each fuel source. Taxes include federal and state excises, state severance taxes, and city and county excises and utility taxes. Table A2.1.12 summarizes the average per unit tax in 1986 for each fuel type. Similarly, Table A2.1.13 summarizes average taxes, but taxes designated for a specific use, e.g. gasoline taxes dedicated to the federal highway trust fund, have been excluded. For some taxes, revenues were allocated over fuel sources because the fuel source could not be readily identified. For example, severance taxes on petroleum were allocated over gasoline, diesel, aircraft fuel, and heating oils. Allocation methods are discussed in detail below. Tables A2.1.12 and A2.1.13 also present taxes for each fuel relative to the total BTU content of each fuel consumed in 1986.

### **Federal Excises**

Taxes on gasoline and diesel fuel were drawn from "Statistics of Income Bulletin" from the IRS, Spring 1987, Table A2.1.12. Excises for gasoline and lubricating oils were \$8,857,380,000 and for diesel and special motor fuels, \$2,613,980,000. The full value of each excise was allocated to gasoline and diesel fuel, respectively. These funds are earmarked for the Federal Highways Trust Fund. These figures differ slightly from Department of Transportation figures for the trust fund in 1986, but the difference is small.

The black lung tax levied on coal was \$561,158,000 in 1986 according to the same source. The entire tax was allocated to coal.

### **Other Federal Taxes**



## **Environmentally Responsible Energy Pricing**

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The windfall profits tax totalled \$8,866,967,000 in 1986, while the superfund tax was \$68,538,000 [IRS, "Statistics of Income Bulletin," Spring 1987, Table 12]. At that time, the windfall profits tax was falling rapidly. The superfund tax has grown significantly since this time. These taxes were allocated over all refined oil products based on the proportion of each product to the total volume of refined products in 1986. Approximately 20 percent of these taxes is not included in the tables because only gasoline, aviation fuel, diesel fuel, and fuel oil are included.

### **State Excises**

State excises for motor fuel were \$14,836,960,000 according to the U.S. Dept. of Commerce "Quarterly Summary of Federal, State, and Local Tax Revenue," Ott/Dec 1986, Tables 3,5. This figure differs slightly from the Department's "Government Finances: State Government Tax Collections in 1987," Table 9. The difference is probably due to revisions in the data. For some states, the latter source specified the amount collected from gasoline, diesel, and aircraft fuel, and other fuels not included in this study. Accordingly, taxes collected on other fuels were deleted from total state excises. The remaining taxes (approximately \$14 billion) were allocated over gasoline, diesel, and aircraft fuel according to 1986 consumption levels. Reviewing the tax policies of individual states indicates that many different policies exist for inclusion/exclusion of aircraft fuel, special fuels, etc. These differences could not be captured in the tax allocations.

State excises for timber were \$83 million; however, the proportion relevant for wood fuel could not be determined. Timber taxes were accordingly excluded from the report.

### **Local Excises**

Local taxes for gasoline and other fuels were \$260,040,000 according to the "Quarterly Summary of Federal, State, and Local Tax Revenue," Ott/Dec, 1986, Tables 3, 5. These taxes were allocated to gasoline, diesel fuel, and aviation fuel according to 1986 consumption levels.

### **Severance Taxes**

State severance taxes on coal were \$463 million, and on oil and gas, \$5,325 million according to the Energy Information Agency's "Monthly Energy Review" of July 1988, Tables FE2, FE4. The coal taxes were allocated to coal. The petroleum and gas taxes were allocated between petroleum and natural gas based on the total BTUS of each consumed in 1986, according to consumption figures published in the U.S. Statistical Abstracts, 1989, Table 929. The petroleum taxes were further allocated to gasoline, diesel fuel, aircraft fuel, and heating oil in the same manner as the windfall profits tax.

### Utility Taxes

State utility tax collections were \$6,022,529,000 according to the Department of Commerce's "Government Finances: State Government Tax Collections in 1987," Table L. No information was available to help allocate these tax collections between fuel-related and nonfuel-related (e.g. telephone) utilities. State utility taxes were therefore not included in the draft report.

City and county taxes for natural gas were \$2,294 million, and city and county taxes for electric utilities were \$15,028 million. These figures were drawn from "Government Finances: City Government Finances in 1986-87," Table 1, and "Government Finances: County Government Finances in 1986-87," Table 1, both published by the Bureau of the Census. According to the Statistical Abstracts of the United States, Table 952, in 1986, 46 percent of electric utility generation was due to coal and 12 percent from fuel oil. The remaining amount was for nuclear, hydro, and natural gas. These percentages were adjusted upward to eliminate natural gas from the total leaving coal with 60.85 percent and fuel oil, 15.87 percent of the nongas electricity generation. Accordingly, \$9,145 million was allocated to coal and \$2,385 to fuel oil.

## 7. CALCULATION OF RELATIVE CARBON TAXES

The carbon taxes calculated below apportion externality costs to different fuel sources based on the carbon content of each fuel type. The results of this approach may differ from other estimates found in the literature. Tax values in dollars are not calculated; rather, the estimates address the appropriate tax magnitude for each fuel source by comparing the tax for each fuel to a common reference, the tax for natural gas.

Estimated carbon taxes for each fuel type are based upon the carbon dioxide content of each fuel. Fuel carbon contents were drawn from Marland (1983). In Table A2.1.14, a relative carbon tax is estimated for each fuel, based upon these carbon loadings. First, the carbon content is converted from emissions of carbon per  $10^9$  joules to emissions per unit fuel (e.g. emissions per gallon of gasoline). Joules were converted to BTUS [ $10^{15}$  joules = 0.948 quadrillion BTUs], and BTUS converted to fuel equivalents using the BTU conversion factors found in the "Monthly Energy Review," January, 1987. This carbon dioxide emissions estimate is divided by the estimated externality cost (in this case for the midpoint of the benefits range assuming 25% emission reduction due to current regulations) to yield a measure of carbon dioxide emissions relative to externality costs per unit fuel--labelled the carbon tax. The relative taxes in the last column of the table are scaled with natural gas equal to one by dividing the carbon tax for each fuel by the value for natural gas.

## 8. SUMMARY OF COLLECTED INFORMATION

Much of the information discussed throughout this research summary is collected in a few simple tables. Tables A2.1.15 and A2.1.16 report the total benefits for each fuel. These tables aggregate over all pollutants the total benefit--by fuel type--of compliance with existing regulations and the total benefit--by fuel type--of reducing emissions to zero. Table A2.1.15 reports these figures assuming a 25% emissions reduction for compliance with existing regulations, while Table A2.1.16 incorporates a 10% emission reduction.

Tables A2.1.17 and A2.1.18 present an overall summary of the unit benefit and unit tax information compiled to date. For each fuel type, the tables present the lower and upper bound of the unit benefits aggregated over all pollutants, summing the benefits of compliance with existing regulations and the benefits of reducing emissions to zero. The midpoint of the unit benefits range is presented as is the modified upper bound based on the  $\text{SO}_4$  mortality estimate from Evans. Net unit taxes from Table A2.1.13 are presented, and both the modified upper bound and the net unit tax are presented as a percent of the 1986 price of each fuel. Table A2.1.17 reports these figures assuming a 25% emissions reduction for compliance with existing regulations, while Table A2.1.18 incorporates a 10% emission reduction.

TABLE A2.1.1: TOTAL BENEFITS DRAWN FROM SOURCE DOCUMENTS AND NET BENEFITS USED IN UNIT BENEFIT CALCULATIONS

POLLUTANT	TOTAL BENEFITS * FOR 1986 AS DRAWN FROM SOURCE DOCUMENT (\$ MILLIONS)		% OF TOTAL RESULTING FROM TRANSPORTATION & FUEL COMBUSTION -	% OF TOTAL ALLOCATED TO AN IDENTIFIED FUEL SOURCE~~	NET BENEFIT AS USED IN STUDY (\$ MILLIONS)	
	LOW	HIGH			LOW	HIGH
LEAD IN GASOLINE	8,566	8,686	1.00	1.00	8,566	8,686
PARTICULATE	1,461	72,206	0.46	0.43	631	31,193
SULFUR OXIDES (EXCLUDING SO <sub>4</sub> MORTALITY)	1,220	1,820	0.85	0.83	1,011	1,509
SO <sub>4</sub> MORTALITY	0	109,230	0.85	0.83	0	90,552
OZONE +	279	6,007	0.55	0.48	133	2,865

\* SOURCE: EPA 1985, EPA 1986a, EPA 1988, RFF 1 ALL BENEFITS NORMALIZED TO 1986.

- PERCENT OF TOTAL EMISSIONS ATTRIBUTABLE TO TRANSPORTATION AND STATIONARY SOURCE FUEL COMBUSTION IN EPA 1990.

--SAME AS PRIOR COLUMN ELIMINATING THE FOLLOWING CATEGORIES: RAILROADS, VESSELS, FARM MACHINERY, INDUSTRIAL MAC] OTHER OFF-HIGHWAY VEHICLES, AND OTHER STATIONARY SOURCES.

+ ASSUMES VOC's ACCOUNT FOR 75% OF OZONE FORMATION AND NOX ACCOUNTS FOR 25%.

TABLE A2.1.2: ANNUAL BENEFIT OF COMPLIANCE WITH EXISTING REGULATIONS

POLLUTANT	NET BENEFIT (\$ MILLIONS)+		EMISSIONS IN BASELINE YEAR* (METRIC TONS)	BENEFIT PER TON EMISSION (\$ MILLION/TON)	
	LOW	HIGH		LOW	HIGH
LEAD	8,566	8,686	32,600	262,775	266,429
PARTICULATE	631	31,193	9,100,000	69	3,428
SULFUR OXIDES	1,011	1,509	23,400,000	43	64
S04 MORTALITY	0	90,552	23,400,000	0	3,870
OZONE**	133	2,865	20,175,000	7	142

+ FROM TABLE 1, FINAL TWO COLUMNS.

• BASELINES DRAWN FROM BENEFITS SOURCE DOCUMENTS:  
LEAD, 1984; PARTICULATES, 1978; SULFUR OXIDES, 1980;  
OZONE, 1984.

• \* SUM OF 75% OF VOC EMISSIONS AND 25% OF NOX EMISSIONS.

TABLE A2.1.3: BENEFITS OF COMPLIANCE WITH CURRENT REGULATIONS  
SUMMARIZED IN BTU-EQUIVALENTS

FUEL SOURCE	GROSS BENEFIT OF COMPLIANCE WITH CURRENT REGULATIONS •		GROSS BENEFIT PER BTU FUEL CONSUMED 1986 +	
	TOTAL BENEFIT (\$ MILLIONS)		(\$/MILLION BTUs)	
	LOW	HIGH	LOW	HIGH
GASOLINE	8,818.49	19,699.64	0.61	1.35
DIESEL	96.98	5,157.93	0.04	1.89
AIRCRAFT FUEL	23.21	1,121.26	0.01	0.50
COAL	1,017.51	86,390.24	0.06	5.23
FUEL OIL	122.79	9,965.96	0.02	1.98
NATURAL GAS	16.16	507.16	0.00	0.03
WOOD	246.88	11,977.02	NA	NA

\* BENEFITS FROM TABLE 1 ALLOCATED TO FUEL SOURCES BASED ON PERCENT  
OF TOTAL EMISSIONS FROM EACH FUEL TYPE. EMISSIONS DATA FROM EPA 1990.

+ TOTAL BENEFIT DIVIDED BY VOLUME OF FUEL CONSUMED (FROM TABLE 5)  
MULTIPLIED BY BTU CONVERSION FACTORS. CONVERSION FACTORS FROM  
“MONTHLY ENERGY REVIEW,” JANUARY, 1987.

TABLE A2.1.4: UNIT VALUE OF BENEFITS OF COMPLIANCE WITH EXISTING STANDARDS-BASE CASE “

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD	TOTALS
LEAD IN GASOLINE	0.07362 - 0.07465 (\$ PER GAL)							0.07362
	7.91 - 8.02% (% OF PRICE)							
PARTICULATE	0.03141 - 0.06963 (\$ PER GAL)	0.00366 - 0.18070 (\$ PER GAL)	0.00115 - 0.05689 (\$ PER GAL)	0.14264 - 7.04944 (\$ PER TON)	0.00073 - 0.03614 (\$ PER GAL)	0.00031 - 0.01510 (\$ PER 1000 CU FT)	1.54488 - 76.35152 (\$ PER TON)	1.69477
	0.15 - 7.48% (% OF PRICE)	0.39 - 19.22% (% OF PRICE)	0.18 - 8.85% (% OF PRICE)	0.43 - 21.17% (% OF PRICE)	0.11 - 5.25% (% OF PRICE)	0.01 - 0.38% (% OF PRICE)	2.50 - 123.59% (% OF PRICE)	
SULFUR OXIDES EXCLUDING SO4 MORTALITY	0.00019 (\$ PER GAL)	0.00078 - 0.00116 (\$ PER GAL)	0.00007 - 0.00010 (\$ PER GAL)	1.15046 - 1.71626 (\$ PER TON)	0.00272 - 0.00406 (\$ PER GAL)	0.00002 - 0.00003 (\$ PER 1000 CU FT)	0.00645 - 0.00962 (\$ PER TON)	1.16062
	0.01 - 0.02% (% OF PRICE)	0.08 - 0.1 2% (% OF PRICE)	0.01 - 0.02% (% OF PRICE)	3.45 - 5.15% (% OF PRICE)	0.40 - 0.59?? (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.01 - 0.02% (% OF PRICE)	
SULFUR OXIDES SO4 MORTALITY	0.00000 - 0.01122 (\$ PER GAL)	0.00000 - 0.06975 (\$ PER GAL)	0.00000 - 0.00622 (\$ PER GAL)	0.00000 - ##### (\$ PER TON)	0.00000 - 0.24341 (\$ PER GAL)	0.00000 - 0.00163 (\$ PER 1000 CU FT)	0.00000 - 0.57728 (\$ PER TON)	0.00000
	0.00 - 1.21% (% OF PRICE)	0.00 - 7.42% (% OF PRICE)	0.00 - 0.97% (% OF PRICE)	0.00 - 309.32% (% OF PRICE)	0.00 - 35.38% (% OF PRICE)	0.00 - 0.04% (% OF PRICE)	0.00 - 0.93% (% OF PRICE)	
OZONE	0.00063 - 0.01362 (\$ PER GAL)	0.00051 - 0.01121 (\$ PER GAL)	0.00016 - 0.04)351 (\$ PER GAL)	0.03128 - 0.67397 (\$ PER TON)	0.0000 - 0.03131 (\$ PER GAL)	0.00067 - 0.01451 (\$ PER 1000 CU FT)	0.06229 - 1.34275 (\$ PER TON)	0.09560
	0.07 - 1.46% (% OF PRICE)	0.05 - 1.19% (% OF PRICE)	0.02 - 0.55% (% OF PRICE)	0.09 - 2.02?4 (% OF PRICE)	0.01 - 0.1 9% (% OF PRICE)	0.02 - 0.37% (% OF PRICE)	0.10 - 2.1 7% (% OF PRICE)	

VISIBILITY●\*\*0

AIR TOXICS FROM●●●  
MOTOR VEHICLES

- ALL VALUES NORMALIZED TO \$ 1986.
- VISIBILITY BENEFITS OF CUREENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.
- \*\* NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

### **Footnotes for Table A2.1.4.**

\* ALL VALUES NORMALIZED TO \$1986.

\*\* VISIBILITY BENEFITS OF CURRENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.

\*\*\* NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

#### **Sample Calculation for Particulates:**

Total benefits from Table 1: \$631 million (lower bound) to \$31,193 million (upper bound). Percent of identifiable fuel related emissions from each fuel source: gasoline 25.96%, diesel 11.36%, aircraft fuel 3.06% coal 17.35%, heating oils 4.05%, natural gas 0.78%, wood 37.43%. Source: EPA 1990.

Multiply total benefit by percent of emissions from each fuel source divided by volume of each fuel consumed in 1986 (from Table 5) to find unit benefit (e.g. benefit per gallon).

For gasoline: \$631 million X 0.2596 / 116,354,196,000 gallons equals \$0.0014 per gallon.

To find unit benefit as a percent of price, divide unit benefit by unit price (from Table 5) and multiply by 100.

For gasoline: \$0.0014 / \$0.931 X 100 equals 0.15 percent of the unit price of gasoline.



TABLE A2.1.5: FUEL CONSUMPTION AND PRICE DATA USED IN UNIT BENEFIT CALCULATIONS

FUEL TYPE	CONSUMPTION (1986)		PRICE (1986)	
GASOLINE	116,354,196,000	GALS	\$0.931	PER GAL
DIESEL	19,625,760,000	GALS	\$0.940	PER GAL
AIRCRAFT	16,805,124,000	GALS	\$0.643	PER GAL
COAL	768,300,000	SHT TONS	\$33.300	PER SHT TON
HEATING OILS	34,979,448,000	GALS	\$0.688	PER GAL
NATURAL GAS	16,221,296,000	1000 <b>FT**3</b>	\$3.960	PER 1000 FT ● *3
WOOD	153,000,000	SHT TONS	\$61.780	PER SHT TON

SOURCE: CONSUMPTION DATA FOR GASOLINE, DIESEL, AIRCRAFT FUEL, NATURAL GAS, AND HEATING OIL FROM BASIC PETROLEUM DATA BOOK. HEATING OIL ADJUSTED TO INCLUDE ONLY NONTRANSPORTATION FUEL USES. COAL AND WOOD FROM AER 1987.

PRICES FOR GAS FROM MONTHLY ENERGY REVIEW, AUGUST, 1990. DIESEL FUEL FROM INTERNATIONAL ENERGY ANNUAL, 1986. COAL FROM AER 1987. AIRCRAFT FUEL AND FUEL OILS PRICES ARE WEIGHTED AVERAGES CALCULATED AS DESCRIBED IN SECTION III.B WOOD PRICE FROM EPA 1986b, WEIGHTED BY 1986 REGIONAL POPULATION WEIGHTS.

TABLE A2.1.6 UNIT VALUE OF BENEFITS OF COMPLIANCE WITH EXISTING STANDARDS-MODIFIED UPPER BOUND "

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OIL	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0736 - 0.0746 (\$ PER GAL)						
	7.91 - 8.02% (% OF PRICE)						
PARTICULATE	0.0014 - 0.0696 (\$ PER GAL)	0.0037 - 0.1807 (\$ PER GAL)	0.0012 - 0.0569 (\$ PER GAL)	0.1426 - 7.0494 (\$ PER TON)	0.0007 - 0.0361 (\$ PER GAL)	0.0003 - 0.0151 (\$ PER 1000 CU FT)	1.5449 - 76.3515 (\$ PER TON)
	0.15 - 7.48% (% OF PRICE)	0.39 - 19.22% (% OF PRICE)	0.18 - 8.85% (% OF PRICE)	0.43 - 21.17% (% OF PRICE)	0.11 - 5.25% (% OF PRICE)	0.01 - 0.38% (% OF PRICE)	2.50 - 123.59% (% OF PRICE)
SULFUR OXIDES EXCLUDING SO <sub>4</sub> MORTALITY	0.0001 - 0.0002 (\$ PER GAL)	0.0008 - 0.0012 (\$ PER GAL)	0.0001 - 0.0001 (\$ PER GAL)	1.1505 - 1.7163 (\$ PER TON)	0.0027 - 0.0041 (\$ PER GAL)	0.0000 - 0.0000 (\$ PER 1000 CU FT)	0.0064 - 0.0096 (\$ PER TON)
	0.01 - 0.02% (% OF PRICE)	0.08 - 0.12% (% OF PRICE)	0.01 - 0.02% (% OF PRICE)	3.45 - 5.15% (% OF PRICE)	0.40 - 0.59% (% OF PRICE)	0.06 - 0.00% (% OF PRICE)	0.01 - 0.0% (% OF PRICE)
SULFUR OXIDES SO <sub>4</sub> MORTALITY	0.0000 - 0.0030 (\$ PER GAL)	0.0000 - 0.0184 (\$ PER GAL)	0.0000 - 0.0016 (\$ PER GAL)	0.0000 - 27.1772 (\$ PER TON)	0.0000 - 0.0642 (\$ PER GAL)	0.0000 - 0.0004 (\$ PER 1000 CU FT)	0.0000 - 0.1523 (\$ PER TON)
	0.00 - 0.32% (% OF PRICE)	0.00 - 1.96% (% OF PRICE)	0.00 - 0.26% (% OF PRICE)	0.00 - 81.61% (% OF PRICE)	0.00 - 9.33% (% OF PRICE)	0.00 - 0.01% (% OF PRICE)	0.00 - 0.25% (% OF PRICE)
OZONE	0.0306 - 0.0136 (\$ PER GAL)	0.0005 - 0.0112 (\$ PER GAL)	0.0002 - 0.0035 (\$ PER GAL)	0.0313 - 0.6740 (\$ PER TON)	0.0301 - 0.0013 (\$ PER GAL)	0.0007 - 0.0145 (\$ PER 1000 CU FT)	0.0623 - 1.3427 (\$ PER TON)
	0.07 - 1.46% (% OF PRICE)	0.05 - 1.19% (% OF PRICE)	0.02 - 0.55% (% OF PRICE)	0.09 - 2.0294 (% OF PRICE)	0.01 - 0.19% (% OF PRICE)	0.02 - 0.37% (% OF PRICE)	0.10 - 2.17% (% OF PRICE)

VISIBILITY \*\*\*

AIR TOXICS FROM \*\*\*  
MOTOR VEHICLES

● ALL VALUES NORMALIZED TO \$1986.

● C VISIBILITY BENEFITS OF CURRENT REGULATIONS  
INCLUDED IN SULFUR OXIDES CATEGORY.

● \*o NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

### **Footnotes for Table A2.1.6.**

\* MODIFIED UPPER BOUND INCORPORATES SO<sub>4</sub> MORTALITY RISK ESTIMATE

FROM EVANS, ET AL. 1984 AS UPPER BOUND RISK LEVEL FOR MORTALITY FROM EXPOSURE TO SO<sub>4</sub>.

ALL VALUES NORMALIZED TO 1986.

\*\* VISIBILITY BENEFITS OF CURRENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.

\*\*\* NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

*For Sample Calculations, see Table 4.*

TABLE A2.1.7: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS  
BASE CASE, ASSUMING 25% EMISSION REDUCTION •

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0104 - 0.0112 (\$ PER GAL)						
	1.12 - 1.20% (% OF PRICE)						
PARTICULATE	0.0042 - 0.1619 (\$ PER GAL)	0.0110 - 0.4202 (\$ PER GAL)	0.0035 - 0.1322 (\$ PER GAL)	0.4278 - 16.3860 (\$ PER SHT TON)	0.0022 - 0.0841 (\$ PER GAL)	0.0009 - 0.0353 (\$ PER 1000 CU FT)	4.6346 - 177.5229 (\$ PER SHT TON)
	0.45 - 17.39% (% OF PRICE)	1.17 - 44.70% (% OF PRICE)	0.54 - 20.56% (% OF PRICE)	1.28 - 49.21% (% OF PRICE)	0.32 - 12.23% (% OF PRICE)	0.02 - 0.59% (% OF PRICE)	7.50 - 287.35% (% OF PRICE)
EXCLUDING SO4 MORTALITY	0.0004 - 0.0006 (\$ PER GAL)	0.0023 - 0.0035 (\$ PER GAL)	0.0002 - 0.0003 (\$ PER GAL)	3.4518 - 5.1493 (\$ PER SHT TON)	0.0082 - 0.0122 (\$ PER GAL)	0.0001 - 0.0001 (\$ PER 1000 CU FT)	0.0203 - 0.0301 (\$ PER SHT TON)
	0.04 - 0.06% (% OF PRICE)	0.25 - 0.37% (% OF PRICE)	0.03 - 0.05% (% OF PRICE)	10.37 - 15.46% (% OF PRICE)	1.19 - 1.77% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.05% (% OF PRICE)
SULFUR OXIDES SO4 MORTALITY	0.0000 - 0.0338 (\$ PER GAL)	0.0000 - 0.2087 (\$ PER GAL)	0.0000 - 0.0182 (\$ PER GAL)	0.0000 - 309.0251 (\$ PER SHT TON)	0.0000 - 0.7305 (\$ PER GAL)	0.0000 - 0.0052 (\$ PER 1000 CU FT)	0.0000 - 1.8216 (\$ PER SHT TON)
	0.00 - 3.63% (% OF PRICE)	0.00 - 22.20% (% OF PRICE)	0.00 - 2.84% (% OF PRICE)	0.00 - 928.00% (% OF PRICE)	0.00 - 106.18% (% OF PRICE)	0.00 - 0.13% (% OF PRICE)	0.00 - 2.95% (% OF PRICE)
OZONE	0.0019 - 0.0409 (\$ PER GAL)	0.0015 - 0.0336 (\$ PER GAL)	0.0005 - 0.0105 (\$ PER GAL)	0.0938 - 2.0219 (\$ PER SHT TON)	0.0002 - 0.0039 (\$ PER GAL)	0.0020 - 0.0435 (\$ PER 1000 CU FT)	0.1869 - 4.0282 (\$ PER SHT TON)
	0.20 - 4.39% (% OF PRICE)	0.16 - 3.58% (% OF PRICE)	0.07 - 1.64% (% OF PRICE)	0.28 - 6.07% (% OF PRICE)	0.03 - 0.57% (% OF PRICE)	0.05 - 1.10% (% OF PRICE)	0.30 - 6.52% (% OF PRICE)
VISIBILITY	0.0003 - 0.0013 (\$ PER GAL)	0.0020 - 0.0082 (\$ PER GAL)	0.0002 - 0.0007 (\$ PER GAL)	3.0176 - 12.0704 (\$ PER SHT TON)	0.0071 - 0.0285 (\$ PER GAL)	0.0000 - 0.0002 (\$ PER 1000 CU FT)	0.0170 - 0.0680 (\$ PER SHT TON)
	0.04 - 0.14% (% OF PRICE)	0.22 - 0.87% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)	9.06 - 36.25% (% OF PRICE)	1.04 - 4.15% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	0.0060 - 0.0386 (\$ PER GAL)	0.0423 - 0.2138 (\$ PER GAL)					
	0.65 - 4.14% (% OF PRICE)	4.50 - 22.75% (% OF PRICE)					

• ALL VALUES NORMALIZED TO \$1986.

### **Footnotes for Table A2.1.7.**

\* ASSUMES STRICT COMPLIANCE WITH EXISTING STANDARDS FOR PARTICULATE, SULFUR OXIDES, AND OZONE ACHIEVE A 25% REDUCTION IN TOTAL EMISSIONS OF EACH POLLUTANT.

ALL VALUES NORMALIZED TO \$1986.

#### **Sample Calculation for Particulate from Gasoline:**

Using unit benefits from Table 4, multiply unit benefit times ratio of emissions remaining to emissions reduced due to strict compliance with existing regulations.

For particulate from gasoline: \$0.0014 (lower bound of unit benefit from Table 4) X (0.75 of emissions remaining / 0.25 of emissions reductions achieved) equals \$0.0042 per gallon of gasoline.

To find unit benefits as a percent of unit price, divide unit benefit by unit price (from

For gasoline: \$0.0042 / \$0.931 X 100 equals 0.45% of the unit price of gasoline.

TABLE A2.1.8: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS  
BASE CASE, ASSUMING 10% EMISSION REDUCTION •

BENEFITS SOURCE	GASOLINE		DIESEL		AIRCRAFT FUEL		COAL		HEATING OILS		NATURAL GAS		WOOD	
LEAD IN GASOLINE	0.0104 - 0.0112													
	(\$ PER GAL)													
	1.12 - 1.20%													
	(% OF PRICE)													
PARTICULATES	0.0127 - 0.6267		0.0329 - 1.6263		0.0104 - 0.5120		1.2837 - 63.4449		0.0066 - 0.3252		0.0027 - 0.1359		13.9039 - 687.1636	
	(\$ PER GAL)		(\$ PER GAL)		(\$ PER GAL)		(\$ PER SHT TON)		(\$ PER GAL)		(\$ PER 1000 CU FT)		(\$ PER SHT TON)	
	1.36 - 67.31%		3.50 - 173.01%		1.61 - 79.62%		3.86 - 190.53%		0. % - 47.27%		0.07 - 3.43%		22.51 - 1112.28%	
	(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)	
SULFUR OXIDES EXCLUDING SO4 MORTALITY	0.0011 - 0.0017		0.0070 - 0.0105		0.0006 - 0.0009		10.3541 - 15.4463		0.0245 - 0.0365		0.0002 - 0.0002		0.0580 - 0.0865	
	(\$ PER GAL)		(\$ PER GAL)		(\$ PER GAL)		(\$ PER SHT TON)		(\$ PER GAL)		(\$ PER 1000 CU FT)		(\$ PER SHT TON)	
	0.12 - 0.18%		0.75 - 1.11%		0.10 - 0.15%		31.09 - 46.3%		3.56 - 5.31%		0.00 - 0.01%		0.09 - 0.14%	
	(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)	
SULFUR OXIDES SO4 MORTALITY	0.0000 - 0.1010		0.0000 - 0.6277		0.0000 - 0.0560		0.0000 - 927.0333		0.0000 - 2.1907		0.0000 - 0.0147		0.000 - 5.1955	
	(\$ PER GAL)		(\$ PER GAL)		(\$ PER GAL)		(\$ PER SHT TON)		(\$ PER GAL)		(\$ PER 1000 CU FT)		(\$ PER SHT TON)	
	0.00 - 10.85%		0.00 - 66.78%		0.00 - 8.71%		0.00 - 2783.88%		0.00 - 318.42%		0.00 - 0.37%		0.00 - 8.41%	
	(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)	
OZONE	0.0057 - 0.1226		0.0046 - 0.1009		0.0014 - 0.0316		0.2815 - 6.0657		0.0005 - 0.0117		0.0061 - 0.1306		0.5606 - 12.0847	
	(\$ PER GAL)		(\$ PER GAL)		(\$ PER GAL)		(\$ PER SHT TON)		(\$ PER GAL)		(\$ PER 1000 CU FT)		(\$ PER SHT TON)	
	0.61 - 13.16%		0.45 - 10.73%		0.22 - 4.91%		0.85 - 18.22%		0.08 - 1.71%		0.15 - 3.30%		0.91 - 19.56%	
	(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)	
VISIBILITY	0.0003 - 0.0013		0.0020 - 0.0082		0.0002 - 0.0007		3.0176 - 12.0704		0.0071 - 0.0285		0.0000 - 0.0002		0.0170 - 0.0680	
	(\$ PER GAL)		(\$ PER GAL)		(\$ PER GAL)		(\$ PER SHT TON)		(\$ PER GAL)		(\$ PER 1000 CU FT)		(\$ PER SHT TON)	
	0.04 - 0.14%		0.22 - 0.87%		0.03 - 0.11%		9.06 - 36.25%		1.04 - 4.15%		0.00 - 0.00%		0.03 - 0.11%	
	(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)		(% OF PRICE)	
AIR TOXICS FROM MOTOR VEHICLES	0.0060 - 0.0386		0.0423 - 0.2138											
	(\$ PER GAL)		(\$ PER GAL)											
	0.65 - 4.14%		4.50 - 22.75%											
	(% OF PRICE)		(% OF PRICE)											

\* ALL VALUES NORMALIZED TO \$ 1986.

TABLE A2. 1.9 UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS  
MODIFIED UPPER BOUND, ASSUMING 25% EMISSION REDUCTION ●

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0104 - 0.0112 (\$ PER GAL)						
	1.12 - 1.20% (% OF PRICE)						
PARTICULATE	0.0042 - 0.1619 (\$ PER GAL)	0.0110 - 0.4202 (\$ PER GAL)	0.0035 - 0.1322 (\$ PER GAL)	0.4278 - 16.3860 (\$ PER SHT TON)	0.0022 - 0.0841 (\$ PER GAL)	0.0009 - 0.0353 (\$ PER 1000 CU FT)	4.6346 - 177.5229 (\$ PER SHT TON)
	0.45 - 17.39% (% OF PRICE)	1.17 - 44.70% (% OF PRICE)	0.54 - 20.56% (% OF PRICE)	1.28 - 49.21% (% OF PRICE)	0.32 - 12.23% (% OF PRICE)	0.02 - 0.89% (% OF PRICE)	7.50 - 287.35% (% OF PRICE)
SULFUR OXIDES EXCLUDING SO4 MORTALITY	0.0004 - 0.0006 (\$ PER GAL)	0.0023 - 0.0035 (\$ PER GAL)	0.0002 - 0.0003 (\$ PER GAL)	3.4518 - 5.1493 (\$ PER SHT TON)	0.0082 - 0.0122 (\$ PER GAL)	0.0001 - 0.0001 (\$ PER 1000 CU FT)	0.0203 - 0.0301 (\$ PER SHT TON)
	0.04 - 0.06% (% OF PRICE)	0.25 - 0.37% (% OF PRICE)	0.03 - 0.05% (% OF PRICE)	10.37 - 15.46% (% OF PRICE)	1.19 - 1.77% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.05% (% OF PRICE)
SULFUR OXIDES SO4 MORTALITY	0.0000 - 0.0089 (\$ PER GAL)	0.0000 - 0.0552 (\$ PER GAL)	0.0000 - 0.0049 (\$ PER GAL)	0.0000 - 81.5317 (\$ PER SHT TON)	0.0000 - 0.1927 (\$ PER GAL)	0.0000 - 0.0013 (\$ PER 1000 CU FT)	0.0000 - 0.4569 (\$ PER SHT TON)
	0.00 - 0.95% (% OF PRICE)	0.00 - 5.87% (% OF PRICE)	0.00 - 0.77% (% OF PRICE)	0.00 - 244.84% (% OF PRICE)	0.00 - 28.00% (% OF PRICE)	0.00 - 0.03% (% OF PRICE)	0.00 - 0.74% (% OF PRICE)
OZONE	0.0019 - 0.0409 (\$ PER GAL)	0.0015 - 0.0336 (\$ PER GAL)	0.0005 - 0.0105 (\$ PER GAL)	0.0938 - 2.0219 (\$ PER SHT TON)	0.0002 - 0.0039 (\$ PER GAL)	0.0020 - 0.0435 (\$ PER 1000 CU FT)	0.1869 - 4.0282 (\$ PER SHT TON)
	0.20 - 4.39?? (% OF PRICE)	0.16 - 3.58% (% OF PRICE)	0.07 - 1.64% (% OF PRICE)	0.28 - 6.07% (% OF PRICE)	0.03 - 0.57% (% OF PRICE)	0.05 - 1.10% (% OF PRICE)	0.30 - 6.52% (% OF PRICE)
VISIBILITY	0.0003 - 0.0013 (\$ PER GAL)	0.0020 - 0.0082 (\$ PER GAL)	0.0002 - 0.0007 (\$ PER GAL)	3.0176 - 12.0704 (\$ PER SHT TON)	0.0071 - 0.0285 (\$ PER GAL)	0.0000 - 0.0002 (\$ PER 1000 CU FT)	0.0170 - 0.0680 (\$ PER SHT TON)
	0.04 - 0.14% (% OF PRICE)	0.22 - 0.87% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)	9.06 - 36.25% (% OF PRICE)	1.04 - 4.15% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	0.0060 - 0.0386 (\$ PER GAL)	0.0423 - 0.2138 (\$ PER GAL)					
	0.65 - 4.14% (% OF PRICE)	4.50 - 22.75% (% OF PRICE)					

● ALL VALUES NORMALIZED TO \$ 1986.

TABLE A2.1 .10: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS  
MODIFIED UPPER BOUND, ASSUMING 10% EMISSION REDUCTION •

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	\$0.0104 - \$0.0112 (\$ PER GAL)  1.12 - 1.20% (% OF PRICE)						
PARTICULATES	\$0.0127 - \$0.6267 (\$ PER GAL)  1.36 - 67.31% (% OF PRICE)	\$0.0329 - \$1.6263 (\$ PER GAL)  3.50 - 173.01% (% OF PRICE)	\$0.0104 - \$0.5120 (\$ PER GAL)  1.61 - 79.62% (% OF PRICE)	\$1.2837 - \$63.4449 (\$ PER SHT TON)  3.86 - 190.53% (% OF PRICE)	\$0.0066 - \$0.3252 (\$ PER GAL)  0.96 - 47.27% (% OF PRICE)	\$0.0027 - \$0.1359 (\$ PER 1000 CU FT)  0.07 - 3.43% (% OF PRICE)	\$13.9039 - \$687.1636 (\$ PER SHT TON)  22.51 - 1112.28% (% OF PRICE)
SULFUR OXIDES EXCLUDING SO <sub>4</sub> MORTALITY	\$0.0011 - \$0.0017 (\$ PER GAL)  0.12 - 0.18% (% OF PRICE)	\$0.0070 - \$0.0105 (\$ PER GAL)  0.75 - 1.11% (% OF PRICE)	\$0.0006 - \$0.0009 (\$ PER GAL)  0.10 - 0.15% (% OF PRICE)	\$10.3541 - \$15.4463 (\$ PER SHT TON)  31.09 - 46.39% (% OF PRICE)	\$0.0245 - \$0.0365 (\$ PER GAL)  3.56 - 5.31% (% OF PRICE)	\$0.0002 - \$0.0002 (\$ PER 1000 CU FT)  0.00 - 0.01% (% OF PRICE)	\$0.0580 - \$0.0865 (\$ PER SHT TON)  0.09 - 0.14% (% OF PRICE)
SULFUR OXIDES SO <sub>4</sub> MORTALITY	\$0.0000 - \$0.0266 (\$ PER GAL)  0.00 - 2.86% (% OF PRICE)	\$0.0000 - \$0.1656 (\$ PER GAL)  0.00 - 17.62% (% OF PRICE)	\$0.0000 - \$0.0148 (\$ PER GAL)  0.00 - 2.30% (% OF PRICE)	\$0.0000 - \$244.5949 (\$ PER SHT TON)  0.00 - 734.52% (% OF PRICE)	\$0.0000 - \$0.5780 (\$ PER GAL)  0.00 - 84.01% (% OF PRICE)	\$0.0000 - \$0.0039 (\$ PER 1000 CU FT)  0.00 - 0.10% (% OF PRICE)	\$0.0000 - \$1.3708 (\$ PER SHT TON)  0.00 - 2.22% (% OF PRICE)
OZONE	\$0.0057 - \$0.1226 (\$ PER GAL)  0.61 - 13.16% (% OF PRICE)	\$0.0046 - \$0.1009 (\$ PER GAL)  0.48 - 10.73% (% OF PRICE)	\$0.0014 - \$0.0316 (\$ PER GAL)  0.22 - 4.91% (% OF PRICE)	\$0.2815 - \$6.0657 (\$ PER SHT TON)  0.85 - 18.22% (% OF PRICE)	\$0.0005 - \$0.0117 (\$ PER GAL)  0.08 - 1.71% (% OF PRICE)	\$0.0061 - \$0.1306 (\$ PER 1000 CU FT)  0.15 - 3.30% (% OF PRICE)	\$0.5606 - \$12.0847 (\$ PER SHT TON)  0.91 - 19.56% (% OF PRICE)
VISIBILITY	\$0.0003 - \$0.0013 (\$ PER GAL)  0.04 - 0.14% (% OF PRICE)	\$0.0020 - \$0.0082 (\$ PER GAL)  0.22 - 0.87% (% OF PRICE)	\$0.0002 - \$0.0007 (\$ PER GAL)  0.03 - 0.11% (% OF PRICE)	\$3.0176 - \$12.0704 (\$ PER SHT TON)  9.06 - 36.25% (% OF PRICE)	\$0.0071 - \$0.0285 (\$ PER GAL)  1.04 - 41.5% (% OF PRICE)	\$0.0000 - \$0.0002 (\$ PER 1000 CU FT)  0.00 - 0.00% (% OF PRICE)	\$0.0170 - \$0.0680 (\$ PER SHT TON)  0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	\$0.0060 - \$0.0386 (\$ PER GAL)  0.65 - 4.14% (% OF PRICE)	\$0.0423 - \$0.2138 (\$ PER GAL)  4.50 - 22.75% (% OF PRICE)					

• ALL VALUES NORMALIZED TO \$ 1986.



TABLE A2.1.11: UNIT BENEFIT VALUE OF SELECTED CLEAN AIR ACT AMENDMENTS EMISSIONS TARGETS

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE							
PARTICULATES							
SULFUR OXIDES EXCLUDING SO4 MORTALITY				\$2.1164 - \$3.1576 (\$ PER SHT TON)	\$0.0019 - \$0.0276 (\$ PER GAL)		
				6.36 - 9.48% (% OF PRICE)	0.27 - 4.01% (% OF PRICE)		
SULFUR OXIDES SO4 MORTALITY				\$0.0000 - \$189.4833 (\$ PER SHT TON)	\$0.0000 - \$0.1658 (\$ PER GAL)		
				0.00 - 569.02% (% OF PRICE)	0.00 - 24.09% (% OF PRICE)		
OZONE	\$0.0012 - \$0.0258 (\$ PER GAL)	\$0.0003 - \$0.0058 (\$ PER GAL)	\$0.0003 - \$0.0073 (\$ PER GAL)	\$0.0021 - \$0.0451 (\$ PER SHT TON)	\$0.0001 - \$0.0020 (\$ PER GAL)	\$0.0001 - \$0.0027 (\$ PER 1000 CU FT)	\$0.1484 - \$3.1955 (\$ PER SHT TON)
	0.13 - 2.75% (% OF PRICE)	0.03 - 0.62% (% OF PRICE)	0.05 - 1.13% (% OF PRICE)	0.01 - 0.14% (% OF PRICE)	0.01 - 0.29% (% OF PRICE)	0.00 - 0.07% (% OF PRICE)	0.24 - 5.17% (% OF PRICE)
VISIBILITY				\$1.3875 - \$5.5512 (\$ PER SHT TON)	\$0.0012 - \$0.0049 (\$ PER GAL)		
				4.17 - 16.67% (% OF PRICE)	0.17 - 0.715 (% OF PRICE)		
AIR TOXICS FROM MOTOR VEHICLES							

● ALL VALUES NORMALIZED TO \$ 1986.

### **Footnotes for Table A2.1.11.**

\* ALL VALUES NORMALIZED TO \$1986.

+ ASSUMES SULFUR DIOXIDE EMISSIONS FROM ELECTRIC UTILITIES WILL BE REDUCED BY 10 MILLION TONS ANNUALLY. EMISSION REDUCTIONS ALLOCATED BETWEEN COAL AND HEATING OILS BASED UPON PROPORTION OF ELECTRIC UTILITY OUTPUT FROM EACH SOURCE. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

<sup>A</sup> ASSUMES OZONE POLLUTION REDUCED BY 10 MILLION TONS ANNUALLY. ASSUMES THAT VOCs ACCOUNT FOR 100 PERCENT OF OZONE FORMATION. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

### **Footnotes for Table A2.1.11.**

\* ALL VALUES NORMALIZED TO \$1986.

+ ASSUMES SULFUR DIOXIDE EMISSIONS FROM ELECTRIC UTILITIES WILL BE REDUCED BY 10 MILLION TONS ANNUALLY. EMISSION REDUCTIONS ALLOCATED BETWEEN COAL AND HEATING OILS BASED UPON PROPORTION

OF ELECTRIC UTILITY OUTPUT FROM EACH SOURCE. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

“ ASSUMES OZONE POLLUTION REDUCED BY 10 MILLION TONS ANNUALLY. ASSUMES THAT VOCs ACCOUNT FOR 100 PERCENT OF OZONE FORMATION. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

Table A2.1.12

## Taxes Per Unit of Fuel Consumption

<u>Fuel Type</u>	<u>Total taxes per Fuel Type (in \$ billions)</u>	<u>Taxes per Unit of Fuel</u>	<u>Taxes as a Percent of of Price</u>
Gasoline	26.87 <sup>1</sup>	.2309 /gallon	24.91
Diesel fuel	5.00 <sup>2</sup>	.2548/gallon	27.14
Aircraft fuel	1.71 <sup>3</sup>	.1019 /gallon	15.53
Natural gas	4.11 <sup>4</sup>	.2536/1000 cu ft	6.40
coal	10.17 <sup>5</sup>	12.6445/short ton	37.97
Fuel oil	4.72 <sup>6</sup>	.1009/gallon	12.07

Note: All figures are in 1986 dollars.

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<sup>1</sup>Includes Federal, state, and local excises, state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated).

<sup>2</sup>Includes Federal, state, and local excises, state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated).

<sup>3</sup>Includes state and local excises, state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated).

<sup>4</sup>Includes state severance taxes, and city and county utility taxes. Excludes state utility taxes. Total for all state utilities over \$6 billion.

<sup>5</sup>Includes state severance taxes, black lung tax, and city and county utility taxes (allocated). Excludes state utility taxes. Total for all utilities over \$6 billion.

<sup>6</sup>Includes city and county utility taxes (allocated), state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated). Excludes state utility taxes. Total for all utilities over \$6 billion.

Table A2.1.13

Taxes Per Unit of Fuel Consumption Net of Taxes  
Earmarked for Specific Programs<sup>+</sup>

<u>Fuel Type</u>	Net Taxes* per Fuel Type (in \$billions)	Net Taxes per <u>Unit of Fuel</u>	Taxes as a Percent of Price	Net Tax Per <u>Million BTU</u>
Gasoline	17.98	.1545/gal	16.60	\$1.24
Diesel Fuel	2.38	.1213/gal	12.90	0.87
Aircraft Fuel	1.71	.1016/gal	15.49	0.76
Heating Oil	4.70	.1005/gal	14.61	0.93
Natural gas	4.11	.2536/cu.ft.	6.40	0.58
Coal	9.61	11.9458/ton	35.87	0.25

● Excludes taxes designated for Federal Highways Trust Fund, Superfund Tax, and Black Lung Tax. Some state and local tax revenues may be designated for specific uses but are not excluded from this table.

+ All figures are for tax year 1986 in 1986 dollars.

TABLE A2.1 .14: RELATIVE CARBON TAXES, ASSUMING 25% EMISSION REDUCTION

FUEL TYPE	POUNDS CO2 EMISSION PER UNIT FUEL+	EXTERNALITY COST PER UNIT ++			RELATIVE CARBON TAX**
		LOW	MIDPOINT	HIGH	
GASOLINE (GALS)	5.48	\$0.10	\$0.28	\$0.46	27.89
DIESEL (GALS)	6.31	\$0.06	\$0.61	\$1.15	52.88
AIRCRAFT FUEL (GALS)	NA	\$0.01	\$0.12	\$0.23	NA
COAL (SHT TONS)	1,219.02	\$8.32	\$232.71	\$457.10	104.87
HEATING OILS (GALS)	6.67	\$0.02	\$0.58	\$1.14	47.99
NATURAL GAS (1000 FT**3)	32.85	\$0.00	\$0.06	\$0.12	1.00
WOOD (SHT TONS)	NA	\$6.47	\$134.11	\$261.75	NA

+ SOURCE: CO2 EMISSIONS FOR EACH FUEL FROM MARLAND 1983.  
 CONVERTED TO POUNDS CO2 EMISSION PER UNIT FUEL BASED UPON  
 CONVERSION FACTORS IN "MONTHLY ENERGY REVIEW," JANUARY 1987.

++ FROM SUMMING DOWN THE COLUMNS OF TABLES 4 AND 7.

\*\* MODIFIED UPPER BOUND DIVIDED BY CARBON CONTENT, SCALED WITH  
 NATURAL GAS EQUAL TO ONE BY DIVIDING THE CARBON TAX FOR EACH FUEL  
 TYPE BY THE CARBON TAX FOR NATURAL GAS.

TABLE A2.1.15: GROSS VALUE OF BENEFITS BY FUEL-ASSUMING 25% EMISSION REDUCTION

FUEL SOURCE	GROSS BENEFIT OF COMPLIANCE WITH CURRENT REGULATIONS •		GROSS BENEFIT OF REDUCTION TO ZERO+	
	TOTAL BENEFIT (\$ MILLIONS)		TOTAL BENEFIT (\$ MILLIONS)	
	LOW	HIGH	LOW	HIGH
GASOLINE	8,818.5	19,699.6	2,708.9	33,528.8
DIESEL	97.0	5,157.9	1,161.0	17,427.6
AIRCRAFT FUEL	23.2	1,121.3	72.6	2,722.9
COAL	1,017.5	86,390.2	5,371.2	264,796.7
HEATING OILS	122.8	9,966.0	618.0	30,056.5
NATURAL GAS	16.2	507.2	49.4	1,367.1
WOOD	246.9	11,977.0	743.4	28,071.0

\* THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM  
TABLE 4 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 5.

+ THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM  
TABLE 7 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 5.

TABLE A2.1.16: GROSS VALUE OF BENEFITS BY FUEL-ASSUMING 10% EMISSION REDUCTION

FUEL SOURCE	GROSS BENEFIT OF COMPLIANCE WITH CURRENT REGULATIONS *		GROSS BENEFIT OF REDUCTION TO ZERO+	
	TOTAL BENEFIT (\$ MILLIONS)		TOTAL BENEFIT (\$ MILLIONS)	
	LOW	HIGH	LOW	HIGH
GASOLINE	8,818.5	19,699.6	4,220.9	105,069.6
DIESEL	97.0	5,157.9	1,742.9	50,778.5
AIRCRAFT FUEL	23.2	1,121.3	212.0	10,103.7
COAL	1,017.5	86,390.2	11,476.0	786,785.8
HEATING OILS	122.8	9,966.0	1,354.5	90,691.3
NATURAL GAS	16.2	507.2	146.2	4,567.5
WOOD	246.9	11,977.0	2,224.5	107,803.5

\* THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM TABLE 4 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 5. (SAME AS IN TABLE 15).

+ THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM TABLE 8 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 8.



TABLE A2.1.17: SUMMARY OF ENERGY EXTERNALITIES AND TAXES-ASSUMING 25% EMISSION REDUCTION							
FUEL TYPE	EXTERNALITY COSTS PER UNIT *		EXTERNALITY COSTS PER UNIT	EXTERNALITY COSTS PER UNIT + MODIFIED UPPER BOUND	MODIFIED UPPER BOUND AS A ++ PERCENT OF PRICE (1986)	NET TAX PER UNIT FUEL - (1986)	NET TAX AS PERCENT OF PRICE ~ (1986)
	LOW	HIGH	MIDPOINT **				
GASOLINE (GAL)	\$0.10	\$0.46	\$0.28	\$0.42	45.58%	\$0.15	16.60%
DIESEL FUEL (GAL)	\$0.06	\$1.15	\$0.61	\$0.95	100.63%	\$0.12	12.90%
AIRCRAFT FUEL (GAL)	\$0.01	\$0.23	\$0.12	\$0.21	32.79%	\$0.10	15.80%
COAL (SHORT TONS)	\$8.32	\$457.10	\$232.71	\$153.78	461.79%	\$11.95	35.87%
HEATING OILS (GAL)	\$0.02	\$1.14	\$0.58	\$0.43	62.08%	\$0.10	14.61%
NATURAL GAS (1000 CUBIC FT)	\$0.00	\$0.12	\$0.06	\$0.11	2.79%	\$0.25	6.40%
WOOD (SHORT TONS)	\$6.47	\$261.75	\$134.11	\$259.96	420.79%	NA	NA

•FROM SUMMING DOWN THE COLUMNS OF TABLES 4 AND 7.

\*\* MIDPOINT OF TWO PREVIOUS COLUMNS.

+ FROM SUMMING DOWN THE COLUMNS OF TABLES 6 AND 9.

++PRICE FROM TABLE 5 DIVIDED BY MODIFIED UPPER BOUND MULTIPLIED BY 100.

- FROM TABLE 13.

TABLE A2.1.18: SUMMARY OF ENERGY EXTERNALITIES AND TAXES-ASSUMING 10% EMISSION REDUCTION

FUEL TYPE	EXTERNALITY COSTS PER UNIT ●		EXTERNALITY COSTS PER UNIT	EXTERNALITY COSTS PER UNIT + MODIFIED UPPER BOUND	MODIFIED UPPER BOUND AS A ++ PERCENT OF PRICE (1986)	NET TAX PER UNIT FUEL ~ (1986)	NET TAX AS PERCENT OF PRICE ~ (1986)
	LOW	HIGH	MIDPOINT **				
GASOLINE (GAL)	\$0.11	\$1.07	\$0.59	\$0.99	106.31%	\$0.15	16.60%
DIESEL FUEL (GAL)	\$0.09	\$2.85	\$1.47	\$2.34	248.59%	\$0.12	1 2.90%
AIRCRAFT FUEL (GAL)	\$0.01	\$0.67	\$0.34	\$0.62	96.76%	\$0.10	15.80%
COAL (SHORT TONS)	\$16.26	\$1,136.50	\$576.38	\$378.24	1135.85%	\$11.95	35.87%
HEATING OILS (GAL)	\$0.04	\$2.88	\$1.46	\$1.09	157.81%	\$0.10	14.61%
NATURAL GAS (1000 CUBIC FT)	\$0.01	\$0.31	\$0.16	\$0.30	7.60%	\$0.25	6.40%
WOOD (SHORT TONS)	\$16.15	\$782.88	\$399.52	\$778.63	1260.3370	NA	NA

●FROM SUMMING DOWN THE COLUMNS OF TABLES 4 AND 8.

\*\* MIDPOINT OF TWO PREVIOUS COLUMNS.

+ FROM SUMMING DOWN THE COLUMNS OF TABLES 6 AND 10.

++ PRICE FROM TABLE 5 DIVIDED BY MODIFIED UPPER BOUND MULTIPLIED BY 100.

## APPENDIX 2.2

SUMMARY OF DRAFT NEW YORK STATE ENERGY PLAN:  
1991 BIENNIAL UPDATE ISSUE 9:  
ENERGY/ENVIRONMENTAL TAXES

Two types of externality taxes are considered in the report. One is the traditional Pigouvian tax approach which is referred to as a general revenue tax. The second approach, called the trust fund tax, is a variation on environmental taxes where the taxes are paid into a trust fund. The trust fund is in turn used to finance abatement measures. While the trust fund approach will not be as economically efficient as the general revenue tax because the pricing mechanism of the Pigouvian approach is diluted, the trust fund tax significantly reduces the tax bill for emitters.

The pollutants for which externality cost estimates are made include sulfur dioxide (SO<sub>2</sub>), nitrous oxides (NO<sub>x</sub>), and carbon dioxide (CO<sub>2</sub>). For SO<sub>2</sub> and NO<sub>x</sub>, estimates are made for electricity generation only. Estimated externality costs are listed in the table.

These figures are based on marginal damages and marginal abatement costs following compliance with the Clean Air Act Amendments of 1990.

For sulfur dioxide, a damage function was specified by first estimating the health risks of SO<sub>2</sub> emissions at the state's tonnage cap of 280,000 tons. The risk estimates were based on New York State population characteristics and a review of available research studies, several of which were included in EPA's assessment of the risks of SO<sub>2</sub> emissions. Resulting risk estimates at the emissions cap were: mortality risk,  $60 \times 10^{-7}$  for exposure at one u/m<sup>3</sup> of SO<sub>2</sub>, estimated number of deaths, 12.44, valuation, \$4 million. For a generic coal plant, emissions of 22,350 tons are valued at \$50 million for an average damage cost of \$2,244 per ton. It was then assumed that at emissions levels below 100,000 tons, damages are diminimus. The risk function was completed by assuming a linear damage relationship between the estimated risk at the tonnage cap and the assumed diminimus level of emissions.

The marginal abatement cost function is a step function derived from the incremental SO<sub>2</sub> reductions which can be achieved with various retrofit technologies. Comparing the intersection of the damage and abatement functions leads to the conclusion that an additional 75,000 tons of emissions should be reduced over and above the emissions reductions in the Clean Air Act Amendments. The optimal tax rate consistent with this

ESTIMATED EXTERNALITY COST (MILLIONS)		
POLLUTANT	TRUST FUND	GEN REVENUE
SO <sub>2</sub>	\$250	\$1,274
NO <sub>x</sub>	\$1,405	\$6,081
CO <sub>2</sub>	\$7.9	\$107

emissions reduction is \$1,274 per ton of SO<sub>2</sub>, measured in 1990 dollars. Following the trust fund approach, the estimated tax would be \$280 per ton.

Due to a paucity of information on the direct risks of NO<sub>x</sub> exposure, a damage function was not estimated; rather, an implied valuation was generated based upon the highest marginal costs previously committed to compliance with NO<sub>x</sub> emissions reductions requirements. It is further assumed that this implied marginal damage value, \$6,100 per ton of emissions reduction at coal-fired utilities, is the optimal environmental tax rate.

Environmental taxes for control of carbon dioxide are also estimated with an implied valuation. The values are based on a 10 percent reduction in carbon emissions from a 1988 baseline. Details of the estimate are not included in this report, but are found in Analysis of Carbon Reduction in New York State (June 1991). The general revenue tax for CO<sub>2</sub> is projected at \$107 per ton emitted, and the trust fund tax at \$7.9 per ton.

### **Contrast with Estimates from Viscusi-Magat**

The pollutants under consideration, the health and environmental endpoints of concern, and the sources of pollution differ markedly between the New York State study and Part II of the report. The New York study considers only sulfur dioxide, nitrous oxide, and carbon dioxide. Several additional pollutants are considered in Part II, including, residual lead in gasoline, air toxics from motor vehicles, particulate, SO<sub>4</sub> and related by-products, and ozone producing VOC's. The class of sulfur-containing compounds and the endpoints valued are considerably broader. In addition to the direct damages of sulfur dioxide, other health and environmental endpoints considered are morbidity, environmental and materials damage, and visibility diminution. Part II of our study may include a narrower set of endpoints for NO<sub>x</sub>, however, because only ozone related effects are considered, not direct health and environmental effects.

The New York State study includes environmental tax estimates aimed at reducing carbon dioxide emissions by 10%; no such estimates are considered in Part II. We do, however, consider the size of a carbon tax which would be required if a carbon tax was used as a mechanism to implement environmental taxes for the externalities created by other pollutants.

Only electricity generation is considered as a source of SO<sub>2</sub> and NO<sub>x</sub>, while we consider all combustion sources, including both transportation and stationary source fuel combustion, composed of fuel use by public utilities, commercial/industrial sources, and private sources such as homeowners. By focusing on utility combustion only, several important fuels will be under represented, especially home heating oils, natural gas, and wood fuel.

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Estimated environmental taxes may differ between the two studies because of significantly different baselines used in the two studies. The New York State study assumes compliance with the Clean Air Act Amendments of 1990 in the baseline from which health effects are measured. We incorporate a 1986 baseline which falls before the expected implementation of the most recent standards for ambient air concentrations of criteria pollutants.

The approaches used to determine the optimal tax rates are similar, but both studies are subject to uncertainty about the methods used. Our study assumes that the adverse effects of pollutants on health and environment are proportional to fuel consumption. The New York State study includes a linear relationship between emissions and adverse effects based upon an assumed no effects threshold for  $\text{SO}_2$ . Because our study includes health effects as a constant proportion to fuel consumption, the optimal tax rate is constant over any level of emissions. The New York study, on the other hand, must also estimate a marginal abatement cost function to help determine the optimal degree of pollution reduction. Estimating this relationship introduces another level of uncertainty.

The environmental taxes for  $\text{NO}_x$  and  $\text{CO}_2$  in the New York State study are based on the assumption that maximum marginal abatement costs reflect the optimal marginal benefit of abatement. The existing environmental regulations which led to these observed expenditures were not based on measures of optimal levels of abatement. Therefore, there is no reason to believe that the observed abatement costs reflect social cost marginal prices.

There is an environmental externality costing research project under preparation by the New York Dept of Public Service, the New York State Energy Research Development Authority, the Empire State Electric Energy Research company, and the Electric Power Research Institute with the objective of developing a methodology for estimating environmental externality costs for electricity generation. The project is expected to be completed in 1994.

PART III:  
OPTIONS FOR AND DISCUSSION OF IMPLEMENTING FULL  
SOCIAL COST ENERGY PRICING

Prices of energy resources can be restored to their full social costs by adopting an optimal taxation schedule. Part II of our report--The Full Social Cost Energy Pricing Approach to Greenhouse Warming Policy--estimated optimal tax levels reflecting air pollution-related costs incurred by society in the consumption of energy from fossil fuels. This part raises issues associated with tax implementation, and discusses some of the approaches available for implementing energy taxes. Options discussed will include different tax approaches which could be undertaken, and the various administrative levels at which taxes could be implemented. These administrative issues also raise related concerns, such as the role of regional pollution variations. The extent to which each approach fulfills the goal of full social cost pricing of energy sources is addressed at length.

### 3.1 TAXATION OPTIONS

A number of different taxes could be used to reflect social costs in energy prices. Pertinent issues associated with each tax are addressed in the accompanying tables. In all cases, the objective of the tax is to link the tax as closely as possible to the damage being caused. Energy sources that are being used in a manner that is less polluting should be taxed less. Incorporating a tax mechanism that will provide incentives for pollution reduction will remain a major challenge.

A consumption tax could be assessed at the retail sale of the appropriate fuels. In some cases, primarily electric utilities, the tax would apply to the sale of the resulting energy rather than the retail sale of the fuel itself. A production/import tax would fall on the producer or importer of the fuel at the point of production or at the time that the fuel was imported into the United States. These two tax approaches, consumption taxes and production taxes are the broadest tax approaches which will be addressed.

A carbon tax assessed on different fuels based on the carbon content of each fuel type also entails broad coverage of all fuel types while playing a second role introducing incentives to reduce consumption of the highest carbon content fuels--those fuels that contribute most to potentially damaging climate change. This should not, however, be interpreted as a tax designed to account for the environmental damages of global warming. As discussed in The Full Social Cost Energy Pricing Approach to Greenhouse Warming Policy (hereafter, Full Social Cost Energy Pricing), this analysis follows a “no regrets” approach to achieving efficient energy prices which is designed to reduce the burden of environmental damages of pollution. These taxes stop short of addressing global warming damages directly due to the current uncertainty in the magnitude--and even the direction--of the effects of climate change. The carbon tax examined in the study uses carbon content-based tax rates to incorporate social costs of conventional air pollutants into energy prices.

Several more narrow taxes could be imposed. A coal output tax would fall on producers and importers of coal. Similarly, a gasoline and diesel fuel tax would be imposed



on consumers at the retail pump. An electricity tax could be collected by electricity generating utilities, much as local and state taxes are collected today. These tax approaches are more narrowly targeted at specific segments of the energy market, but could be implemented in combination to provide broader coverage.

An alternative approach to any of these tax schemes is imposing a fee on pollution emissions. The revenues collected under an emissions fee approach would be equivalent to collections using the traditional tax approach, but such fees introduce new administrative demands on pollution emitters and regulators. Their advantage is that there will be a close link between the tax and the environmental costs.

Each of these tax approaches could be administered at any level of government, from local governments to the federal level. The greatest advantage of nationwide implementation is ease of coordination and refinement of the appropriate tax levels. At more localized administrative levels, taxes could be adjusted to account for the particular characteristics of that jurisdiction, enhancing fuel resource allocation, but coordination across jurisdiction may become unmanageable.

Local taxes may also induce inefficiencies. A tax levied by the state of Virginia may lead Northern Virginia residents to buy their gasoline in Maryland or the District of Columbia.

### 3.2 CRITERIA FOR EVALUATING TAX APPROACHES

A number of questions should be asked of each social cost pricing implementation strategy. Perhaps the most important issue is the extent to which the tax scheme fulfills the goal of incorporating unpriced social costs specifically attributable to use of an energy source in the market price of each fuel.

The implementing jurisdiction and the effects of that level of control should be considered for each tax approach. If taxes implemented at the local level preclude updating the tax rates, then more broadly based implementation would be advantageous. On the other hand, local control would be more desirable if more sensitive, localized, information was incorporated in tax rates. As an example, pollution levels in Los Angeles may merit quite different taxes than pollution in Sacramento.

Ease of tax collections is also a pertinent factor. For some tax approaches, tax collection mechanisms already exist. For example, gasoline and diesel taxes levied nationally as well as by states and localities are collected at point of sale. State severance taxes are collected at the wellhead for petroleum production, and utilities commonly collect taxes through their customers' regular billing. No systems currently exist for collecting fees from pollution emitters at the emissions point.

The degree of difficulty associated with updating the tax rates may also vary depending on the tax approach.

One final issue which will be identified is the end use marketplace effects of each tax type. While appropriately calibrated taxes would cause fuel consumption to adjust optimally, divergences from optimal taxes may have nonoptimal distortionary effects in end product markets.

### 3.3 OBJECTIVE OF FULL SOCIAL COST PRICING

Prices act as the marketplace signal to allocate goods and services among producers/sellers and consumers. To achieve the efficient allocation, market prices should reflect the full cost of supplying a good. The adverse marketplace implications of pollution arise because pollution damages, and the true costs of the production of a commodity such as energy, are often not reflected in market prices. In the case of energy consumption, market prices reflect the private costs of consumption, but not the environmental consequence.

Air pollution, the subject of this research effort, is shown in Full Social Cost Energy Pricing to be a substantial cost of energy consumption. Excluding pollution costs from energy prices creates inadequate incentives for optimal resource allocation. It has been shown by economists since the time of Pigou that incorporating an appropriate tax in the price of a commodity priced below its full social cost can create a signal leading buyers and sellers to optimal resource allocation. One of the purposes of this research effort has been to calculate the appropriate tax rates on energy resources incorporating the full social costs of energy production and consumption in the market price signal.

### 3.4 LIMITATIONS ON THE OBJECTIVE OF OPTIMAL TAXES

In practice, due to data limitations, technological and scientific uncertainty, and resource constraints, computing the precise tax rates to restore optimal resource allocation is an impossible task. A number of different sources of underlying uncertainty are discussed in the appendices to Full Social Cost Energy Pricing. The issue of regional variation is of particular concern with respect to the choice of the tax implementation approach. Truly optimal tax rates should vary on a regional or even localized level when environmental and/or health damages vary.

Regional variation involves two classes of issues. First, different regions suffer varying degrees of environmental damage and health degradation from pollutants related to energy consumption. Differences may occur in different regions of the country such as East and West, urban versus rural environments, and even across local areas with differing microclimates. Some environmental pollutants may be of great concern in one area but not

as significant in other areas. Ozone is of greatest concern in urban areas, most especially the Los Angeles Basin, while sulfur dioxide pollution--the main precursor to acid precipitation--is of greater concern in the Midwest and Northeast, often in less populated areas.

A second dimension of the regional nature of pollution is that the source of pollution may not be the area that incurs the adverse consequences. Ozone pollution from urban areas may blow across rural areas reducing agricultural output. The sulfur dioxide emissions of a few electricity generating power plants in the Midwest may be responsible for acid precipitation over a much broader area.

Optimal taxes should take both of these considerations into account. Localized tax rates should account for the specific health and environmental damages of the emissions in the local area and any downstream consequences of those emissions. Relative to the single tax rates computed in Full Social Cost Energy Pricing taxes in Los Angeles, for example, are probably too low for ozone pollution and may be too high for sulfur oxides. Ozone pollution from Los Angeles blows across a wider region, threatening both agricultural output and human health. But because the damages from sulfur oxides are greatest in the Midwest and Northeast, the single tax rate for sulfur oxides may be higher than is optimal for Los Angeles. In contrast, in large portions of the country, especially rural areas, energy consumption may be responsible for de minimus health and environmental damages from airborne pollutants, and the single tax rates imposed on energy in those areas maybe higher than optimal resource allocations call for.

The above discussion of the direction of regional divergences from optimal tax rates is necessarily inconclusive. Herein lies the difficulty in incorporating full social costs in market prices. Determining the desirable tax rate for a region or locality to reflect the health and environmental damages due to energy consumption in that area places an enormous information burden on policy makers. For the Los Angeles area, several studies have examined the consequences of ozone pollution. Other studies have identified the differences in adverse consequences of ozone exposure in rural versus urban areas. These studies are time consuming, data intensive, and subject to scientific uncertainty.

The tax rates computed in Full Social Cost Energy Pricing are subject to similar constraints. Due to resources limitations and data availability, national emissions estimates and nationwide damage estimates underlie the social cost calculations. Before implementing such a tax approach, however, it would be necessary to conduct a more detailed analysis of the factors influencing variations to reflect more localized conditions.

The practical application of incorporating health and environmental social costs in energy pricing necessitates the balancing of achieving optimality and effectively implementing the tax policy. Some tax approaches may be easier to implement, but with the disadvantage

that regional variation may be more difficult to incorporate. Others may be appealing because of local flexibility, but tax refinement may be more difficult to coordinate. Each of the tax approaches will be discussed below.

### **3.5 BROAD-BASED IMPLEMENTATION OPTIONS**

The broad-based tax alternatives come closest to achieving social cost pricing because all fuel types fall under the tax. Some broad-based taxes inhibit flexibility because incorporating localized information may be impractical. Broad-based taxes are summarized in the first three columns of Table A3.1.1 and for emissions fees, in Table A3.1.2.

#### **Consumption Tax**

A consumption tax would fall on fuel consumers at the point of purchase of the fuel or in some cases for purchase of the energy produced from the fuel. The tax could be administered centrally or on a state or local basis. Fuel taxes are already collected on most consumer purchases of gasoline, diesel fuel, aircraft fuel, and heating oils. While the final buyers of most supplies of coal and substantial quantities of natural gas and heating oils are electric utilities, taxes on those fuels could be passed through to electricity customers. New tax collections would have to be introduced on sales of wood fuel in most cases.

Because taxes would be collected at the point of sale/supply, incorporating differing tax rates for different regions would be possible, but coordinating differentiated tax rates across the different fuels and local jurisdictions may be unwieldy. Updating tax rates because of new or improved scientific or emissions data may be difficult to coordinate as well. Because the tax would fall on all fuels in relation to the emissions from that fuel, consumption levels of each fuel would adjust optimally.

#### **Production/Import Tax**

A tax on producers and importers could be levied at the point of production or importation of each fuel and subsequently passed along to end users in price adjustments. Collection of such a tax would be relatively uncomplicated because of the smaller number of producers/importers and because taxes are already collected from producers in the form of severance and importation taxes. More centralized administration of the tax would be appropriate due to the smaller number of producers/importers. New collections would have to be introduced for wood fuel.

Because a production tax would be targeted toward petroleum rather than the derivative petroleum fuels, this tax is more indirectly linked to the externalities incorporated in energy prices. The market mix of petroleum derived fuels could be distorted as well.

This tax would be one of the easiest taxes to update based on new information, but at the same time is not readily adjustable for local and regional information. Because the tax is collected from only a small number of producers and importers (relative to the large numbers of retailers) and because they are further distanced from actual consumption of the fuels, a more limited information set would be required to refine tax rates. But this same distancing prevents adjusting tax rates at the local level.

### **Carbon Tax**

The carbon tax as utilized in this approach would be used as a mechanism to incorporate the social costs of conventional pollutants in fuel prices based on the carbon loading of each fuel. As discussed in Full Social Cost Energy Pricing this is not a tax explicitly designed to curb greenhouse gas emissions; that is, however, a secondary effect of this approach. This approach is one step removed from the socially optimal pricing schedule because taxes on each fuel are not directly established based on the health and environmental damages of that fuel, but are tempered by the carbon content of the fuel. Some carbon content-based price incentives are thereby introduced but at the cost of a suboptimal allocation of fuel resources relative to conventional air pollutants.

The carbon-based tax could be introduced as either a consumption tax or a production/importation tax with the advantages and drawbacks of each discussed above.

This is a more difficult tax to update because of the need for additional information on carbon loadings of each fuel type and the inherent variations in carbon content across different sources of the same fuel. Introducing regional or local variation is also increasingly complex because of the information requirement of the carbon content of fuels used in that region or locality.

In the marketplace for fuels, the carbon tax will introduce an incentive to reduce consumption of high carbon content fuels, especially coal and natural gas. These marketplace adjustments may not optimally account for air pollution externalities, for example, natural gas has a high carbon loading but a relatively small adverse impact on the environment or health.

### **Emissions Fees**

Fees assessed on the emissions of pollutants are an alternative broad-based implementation method. This approach yields the closest possible linkage between the source of the externality and the assessment of the tax. Fees would be assessed on the pollutant of concern, rather than on the fuel source. Emissions fees would be passed through in the prices of fuels allowing for optimal allocation between fuels in the marketplace.

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The disadvantages of emissions fees have been widely discussed in the environmental economics literature. An emissions fee program may be perceived as transferring to the polluter a pollution property right. This aspect of the fee approach has made fees politically unattractive to groups concerned with whether pollution victims are compensated. Collecting the taxes may be more difficult as well because of the need to collect specific data on emissions from each facility. Collecting emissions data from individuals--for example, for their home furnaces and woodstoves--could be unmanageable. Some estimated level of emissions charges would probably be required from homeowners.

To some extent, emissions fees already incorporate local and regional circumstances because the fees adjust to the emissions in that locality if the fee levels properly incorporate the resulting adverse health and environmental impacts. Some local adjustments could still be incorporated ~~taking into account background levels of each pollutant, dispersion patterns,~~ etc.

### **Targeted Taxes**

Targeted taxes are more narrowly focused than the consumption and production tax approaches, but may be more easily implemented by local authorities. Some targeted taxes may be more readily adjusted on a regional basis compared to a more general tax. These taxes are however, further removed from the notion of optimal resource allocation because only a limited number of pollution sources are targeted by the tax. Marketplace adjustments among fuel types may be undesirable. Targeted taxes are summarized in the final three columns of Table A2.1.1.

### **Gasoline and Diesel Fuel Tax**

A tax on purchases of motor fuels would address only a limited amount of total pollutants from energy consumption. Taxes would be collected at the retail level much as federal, state, and local excises are collected today. Current tax collection would allow for ease of implementation at either a centralized or local level and ready adjustment on a local or regional level. Updating taxes would be relatively simple as the required information set is restricted to motor fuels, only.

A significant drawback to relying strictly on a motor fuels tax is that the greatest quantity of externalities resulting from fuel consumption is not covered. As discussed in the appendices to Full Social Cost Energy Pricing, sulfur oxides pollutants from burning fossil fuels account for the greatest quantity of adverse health effects and for acid precipitation. Only a small amount of sulfur oxides emissions are addressed by a gasoline tax. The same drawback holds for particulate pollution. Limited benefits will be achieved by focusing only on motor fuels. On the other hand, taxing motor fuels will address substantial amounts of

air toxics resulting from motor fuels, residual lead remaining in gasoline, and the precursors to ozone pollution, volatile organic compounds and nitrous oxides.

### **Coal Output Tax**

Like the gasoline tax, a coal output tax addresses a restricted set of sources of conventional pollutants. In that sense, a coal output tax will result in a less than optimal resource allocation. This tax does, however, address the largest single polluting fuel source. Consumption of coal for fuel accounts for the greatest portion of acid precipitation and health effects of sulfur oxides. Substantial amounts of the precursors to ozone are also products of coal consumption.

As with the production tax discussed above, taxes could be collected from a limited number of suppliers providing for ease of implementation. These suppliers are somewhat removed from local fuel consumption, making local administration of the tax and adjustment of the tax rates unworkable.

Much like the case for the gasoline tax, updating the tax rates would be relatively simple because of the more narrow focus of this approach. Also as is the case with the motor fuels tax, there will be marketplace incentives to reduce coal consumption which may not yield an optimal resource allocation.

### **Electricity Tax**

A tax on electricity would be one step removed from a more direct tax on fuel consumption. In this case, electricity generators would tax consumers for their electricity use, electricity which could be generated from a number of different combinations of coal, heating oils, and natural gas.

An electricity tax shares many of the same advantages and disadvantages of the motor fuels and coal output taxes discussed above. This tax focuses on a restricted set of the fuels that create conventional air pollutants, but significant environmental and health endpoints are addressed. Electric utilities are primarily responsible for the emissions of pollutants which lead to acid precipitation, and the large quantities of coal and heating oils consumed by electric utilities account for a substantial portion of the health and environmental effects of sulfur oxides.

Administering an electricity tax at the local level provides a substantial opportunity to readily adjust tax rates for the health and environmental effects specific to that region's facilities. Supervisory and administrative boards overseeing public utilities already exist in most areas. Some broader coordination would probably be required to insure that the adverse impacts occurring downstream from the facilities, as is the clearly the case with acid

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precipitation which may occur far from the generating facilities, are properly incorporated in local tax rates.

Taxing electricity would create incentives for utility customers to consume fuels directly. Large customers like factories and businesses may wish to burn fuel on-site while homeowners may rely more heavily on furnaces for heat. These incentives may lead to undesirable emissions being shifted from electricity-generating facilities to homes and businesses.

### **Combinations of Targeted Taxes**

Implementing some combination of targeted taxes could be used as a means to achieve broad coverage, incorporate local control, and take advantage of administrative simplicity. For instance, a coal output tax could be easily implemented and operated at the federal level while a tax on electricity generation is used to adjust tax rates based on local circumstances. Additional research would be required to address the different combinations of taxes possible and the consequences for approaching an optimal resource allocation of each different approach.



## APPENDIX 3.1

Table A3.1.1

## Alternative Tax Structures

	Consumption Tax	Production/ Import Tax	Carbon Tax	Coal Output Tax	Electricity Tax	Gasoline and Diesel Fuel Tax
Description of Tax	Tax assessed at retail level for all fuel types.	Tax assessed at producer/importer level. Primarily assessed on coal, petroleum and natural gas.	Tax assessed at retail level for all fuel types. Tax amount determined by carbon content of each fuel.	Tax assessed at producer/importer level for all coal except coal used in coking process.	Tax assessed at electricity generating utility.	Tax assessed at retail gasoline outlets.
Level of Tax <sup>1</sup>						
Gasoline	\$0.28/gal		\$ 0.25/gal <sup>4</sup>			\$0.28/gal
Diesel	0.61/gal		2.81/gal			0.61/gal
Aircraft	0.12/gal		NA			
Coal	232.71/ton	\$232.71/ton	142.30/ton	\$232.71/ton		
Heating Oils	0.58/gal		1.43/gal			
Natural Gas	0.06/1000 cu. ft.	0.06/1000 cu. ft.	0.06/1000 cu. ft.			
Wood	134.11/ton	134.11/ton	NA			
Petroleum		11.25/bbl <sup>3</sup>				
Electricity					\$ 0.0665/KWH <sup>5</sup>	
Total Tax Revenue for 1989 estimated consumption volumes (in billions \$) <sup>2</sup>	284.99	288.34	259.38 <sup>6</sup>	197.37	184.92	44.31
Range of Tax Revenue: lower and upper bounds (in billions \$)	21.41 - 548.36	22.45 - 554.03	21.51 - 497.53	7.06 - 387.68	6.67 - 363.45	12.50 - 75.91

Table A3.1.1 (continued)

Scope of Coverage	Broadest coverage.	Broadest coverage.	Broad coverage. Addresses especially fuels linked to climate change, acid rain and sulfur oxide-related effects.	Narrow coverage. Addresses only one fuel source, though most polluting source.	Narrow coverage. Addresses only one set of emissions sources.	Narrowest coverage. Motor vehicles only.
Linkage to Externality	Taxes assessed on each fuel based on contribution to total externality. Closest possible linkage.	Taxes on petroleum based fuels linked to externality indirectly.	Taxes linked to air pollution externalities only indirectly. Extent of externality based on contribution of each fuel type, while tax is based on carbon content.	Close linkage for a narrow set of externalities. Addresses the single most polluting fuel.	Upstream link to externality. Primarily dresses acid rain and other sulfur oxide-related effects.	Close linkage for a narrow set of externalities.
Ease of Collection	Tax collected through existing channels (in most cases). New collections instituted for wood.	Tax collected through a limited number of producers importers. Easiest possible collection. New collections instituted for wood.	Tax collected through existing channels, however, tax will be based upon fuel composition rather than sales volume.	Tax collected at producer/ importer level. Easiest possible collection.	Tax collected at electric utilities, a readily identifiable selection of facilities with existing tax collection mechanisms.	Tax collected through existing channels.
Ease of Refinement <sup>7</sup>	Requires updated information on consumption volumes.	Requires updated information on consumption volumes.	More difficult tax to update. Requires continual updating of carbon content of each fuel type and information on consumption volumes.	Requires updated information on coal consumption volume.	Requires updated information on electricity generation, fuel consumption values and fuel mix by electric utilities.	Requires updated information on gasoline/ diesel consumption volume.
Effects in Fuel Markets	Fuel consumption will adjust optimally to account for externalities.	Could distort market mix of petroleum derived fuels.	In long-run should drive market toward lower carbon-containing fuels, but will not optimally account for air pollution externalities.	Could distort fuel input use away from coal.	In long-run could lead to lower demand for electricity or fuel switching by utilities toward less polluting fuels.	May lead consumers to travel less, switch fuels, or switch transit mode.

Table A3.1.1 (continued)

Institutional Issues	Federal implementation allows easiest coordination. State or local more difficult to coordinate, but could take advantage of existing programs. Collection processes currently exist at Federal level for motor fuels taxes and black lung tax on coal, at state and local level for motor fuels excises and electric utilities.	Federal implementation easiest. State possible. Because production tax could be collected from many fewer parties capered to a consumption tax, state implementation more feasible. Severance tax collection processes exist in many states for these fuels.	Federal implementation easiest. State or local possible but more difficult to coordinate. May be too unweildy for state or local, especially due to continual updating of optimal tax based on carbon content.	Federal, State possible. At state level, severance tax collection mechanisms already exist. At Federal level, black lung tax is currently assessed on coal.	Federal, state, or local implementation possible. Utility taxes currently collected by states and locally. No current Federal tax collection from utilities.	Federal implementation easiest. State/ local possible. Existing tax collection mechanism at federal level for highway trust fund. States and totalities have collection systems for motor fuels taxes.
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### **Footnotes for Table A3.1.1**

1. Consumption tax estimates from appendix table 17, column 4. Represents midpoint of estimated range assuming current regulations reduce emissions by 25% (for SOX and particulate). Estimates of other tax approaches use the consumption tax values as a baseline. Adjustments to the baseline are explained in the appropriate footnotes.
2. Sum over all fuel types of optimal tax (midpoint estimate) for each fuel multiplied by most recent estimate of consumption of that fuel.
3. Per barrel tax on petroleum calculated as tax constraint divided by 1986 petroleum consumption. Tax constraint calculated as sum of optimal tax on gasoline, diesel fuel, aircraft fuels, and heating oils multiplied by base year (1986) consumption volumes.
4. Tax constraint calculated as sum of optimal tax on gasoline, diesel fuel, coal, heating oils, and natural gas multiplied by 1986 consumption volumes for each fuel. Aircraft fuel and wood fuel were deleted due to insufficient carbon content data. Tax constraint was reallocated based upon relative carbon tax weights from appendix table 14.
5. Tax constraint divided by total electric utility industry output for 1986 (source: U.S. Bureau of the Census, Statistical Abstract of the United States, Washington, D.C. (1989), Table 952), Tax constraint calculated as sum of optimal tax on coal, natural gas, and heating oils times volume of each fuel consumed in electricity generation in 1986. Fuel consumption values drawn from (coal and natural gas) or calculated from (heating oils) Annual Energy Review, 1987, Tables 70, 76, and 86.
6. Excludes carbon taxes on aircraft fuels and wood fuel.
7. Based on underlying linearity of benefits models, unit value of benefits (hence, optimal tax values) will be constant for any level of fuel consumption. If, however, linearity does not hold, optimal tax values must be reassessed as fuel consumption values change.

Table A3.1.2

## Emissions Fee

	Emissions Fee
Description of Fee	Fee charged to emitters for each unit of pollutant emitted.
Level of Tax'	
Lead in Gasoline	\$284.82/kilo
Part iculates	18.09/kilo
So <sub>x</sub>	11.13/kilo
NO <sub>x</sub>	0.09/kilo
VOC's	0.71/kilo
Total Tax Revenue for 1988 Emissions Levels'	\$246.83 billion
Range of Tax Revenue: lower and upper bounds (in billions \$)	10.25 - 483.30
scope of Coverage	Broad coverage.
Linkage to Externality	Closest Possible linkage. Fees assessed on each pollutant.
Ease of Collection	Tax collected from each emitter based upon pollutant output. Will require plant-specific monitoring or estimation. New methods will be required for fee collection from auto use.
Ease of Refinement	Requires updated information on national emissions of each pollutant from each fuel type.
Effects in Fuel Markets	Fuel consumption will adjust optimally to account for externalities.
Institutional Issues	Federal implementation. May be too unweildy for state or local given requirements for monitoring/estimation. Implies giving pollution property right to emitters; hence, may be politically unppopular.

**Footnotes for Table A3.12**

1. Emissions fee calculated as midpoint of range of total benefits for each pollutant type from appendix tables 4 and 7 divided by base year emissions. Base year 1986 except 1984 for lead in gasoline.
2. Total tax revenue calculated as sum over each pollutant type of optimal fee (midpoint) times emissions for most recent year, 1989.

## PART IV

# RESIDENTIAL ENERGY DEMAND AND THE TAXATION OF HOUSING

The primary author of this section was William M. Gentry, Economics Professor, Duke University.



Increased concern about the environment has increased interest in policies aimed at reducing energy demand. To address environmental externalities associated with energy consumption, economists often suggest targeting corrective energy taxes.<sup>1</sup> While narrowly focused energy taxes are powerful instruments for reducing energy demand, optimal tax theory suggests that the taxation of substitutes and complements can play an important role in commodity tax design: taxes on complements to energy and subsidies on substitutes for energy reduce energy demand. This paper analyzes the effect of the tax treatment of housing on the demand for energy.

With almost 50 percent of the U.S. capital stock devoted to housing, even a small interaction between the tax treatment of housing and energy demand could induce a large change in energy use. The link between the housing stock and energy demand is direct: housing services are produced by combining houses and residential energy. Estimates from Quigley (1984a) suggest that utility expenditures are about 17 percent of the total annual cost for housing services.<sup>2</sup> In turn, residential energy demand is an important component of total U.S. energy demand: in 1988, residential space heating and cooling, water heating, and other household appliances accounted for 16.4 quadrillion BTUS of energy --20 percent of the total energy consumed in the U.S.<sup>3</sup>

If consuming more housing increases residential energy demand, then reducing the demand for housing reduces energy demand. Rather than discouraging housing consumption, however, U.S. tax policy encourages consumption of and investment in housing. The tax code favors housing in three ways: (1) for homeowners, imputed rents are not taxed and mortgage interest and property taxes can be deducted from income; (2) for rental property, landlords benefit from provisions such as accelerated depreciation; and (3) the corporate income tax induces investment in non-corporate assets, such as housing, rather than the corporate sector. Section 1 of the paper reviews the public finance literature on the taxation of housing and estimates the size of the subsidy to housing from the tax system.

While the tax-treatment of housing may increase housing expenditures, it is less clear whether this increase translates into an increase in residential energy demand. Housing expenditures purchase a bundle of housing attributes: size, location, vintage, design, quality of construction are but a few. Some of these attributes increase energy demand (e.g., size); others, such as energy-efficient design, decrease energy demand. However, both increased size and energy efficiency increase the value of a house. Moreover, residential energy consumption encompasses a variety of end uses: the most important are space heating, water heating, air conditioning and kitchen appliances. Some of these uses of energy are more related to the amount of housing than others. For example, energy for space heating depends directly on the size of the house, but energy for water heating depends more on the number of residents than the size of the house. Section 2 explores the relation between the components of energy demand and house characteristics.

In order to analyze whether changing the tax treatment of housing would affect energy demand, it is necessary to abstract from the intricacies of different house characteristics and uses of energy. Section 3 models housing services as being produced from housing capital (land plus structures) and energy. Changing the tax treatment of housing raises the cost of housing services and increases the price of housing capital relative to the price of energy. This change in relative price reduces the level of housing services consumed and, for a given level of housing services, induces a substitution of energy for capital. The total effect on residential energy demand is the sum of the reduction in energy caused by lower housing consumption and the increase in energy caused by the substitution of energy for capital. The model and estimates draw heavily from Quigley's (1984) estimates on how changes in energy prices affect housing consumption. The estimates suggest that eliminating the tax differential between housing and corporate capital would reduce residential energy demand by 6.8 percent.

Section 4 places the change in residential energy caused by changing the taxation of housing in a broader context. Less consumption of housing services might reduce residential energy, but energy policy is more concerned with total energy demand. Less investment in housing capital might increase investment in other sectors; less consumption of housing services might increase consumption of other goods. This shift from housing to other goods would increase energy used to produce these other goods. Section 4 discusses the implications of changes in residential energy demand on total energy demand and other issues that are not addressed by the model of housing services. Section 5 offers concluding remarks.

## **4.1 THE TAX SYSTEM AS A SUBSIDY TO HOUSING**

The tax subsidy to housing in the U.S. has three main components: (1) preferential treatment of owner-occupied housing from the personal income tax system; (2) tax provisions for rental property such as accelerated depreciation allowances; and (3) general equilibrium effects from corporate taxation. This overall subsidy suggests that, relative to a tax system that is neutral towards housing, the US. invests more in housing, invests less in other assets (e.g., less manufacturing) and consumes less of other goods. This section discusses the three components of the tax treatment of housing and summarizes the overall effect of the tax system.

### ***Tax Incentives & Owner-Occupied Housing***

Because of the importance of housing as a commodity and the magnitude of the revenue costs of the special tax Provisions, an extensive literature details how taxes affect housing prices and demand (see Rosen (1985) for a review). Following Poterba (1984, 1990), for taxpayers who itemize deductions, the after-tax user cost of capital for owner-occupied housing is:

$$\frac{c_o}{P_o} = (1 - \Theta)(i + \tau_p) + \delta + \alpha + m - \pi_o \quad (1)$$

where  $c_o$  is the after-tax user cost of owner-occupied housing,  $\Theta$  is the individual's marginal tax rate,  $i$  is the nominal interest rate,  $\tau_p$  is the property tax rate as a fraction of the value of the house,  $\delta$  is the physical depreciation rate for the house,  $\alpha$  is the risk premium for housing investments,  $m$  is the cost of home maintenance as a fraction of the house value,  $\pi_o$  is the expected rate of house appreciation,  $P_o$  is the price of owner-occupied housing.

At first glance, the tax system only appears to affect the user cost by reducing the cost of homeownership through the deductibility of mortgage interest and property taxes. While the deductibility of mortgage interest and property taxes are among the most visible parts of the tax subsidy for housing, many other tax provisions affect housing. First, implicit in equation (1) are the assumptions that individuals can borrow or lend at the nominal interest rate,  $i$ , and that interest income is taxed at the rate,  $\Theta$ . Under these assumptions, the user cost does not depend on the percentage of the house that is financed by borrowing: housing is a tax- advantaged investment even if it is 100 percent equity financed. This invariance between debt and equity finance highlights the source of the tax incentives for homeownership: imputed rent (implicit income from consumption flows) is not taxed. Instead of creating a tax advantage for housing, mortgage interest deductibility merely extends the tax advantage of equity-financed housing to homeowners who borrow (see Woodward and Weicher (1989)).

Second, this user cost expression does not hold for households who do not itemize. Although the after-tax interest rate is still appropriate for the equity position of the non-itemizer, since the return on alternative investments is taxed, non-itemizers pay the before-tax interest rate and the full value of property taxes ( $\Theta = 0$ ).<sup>5</sup> Third, the user cost depends on the household's marginal tax rate which varies across households. Therefore, the user cost depends on the other characteristics (mainly, income) of the household that affect tax rates. The dependence of the user cost on household tax rates makes it difficult to separate income and tax effects in empirical work since the tax rate varies directly with income. Fourth, this user cost formula assumes that the price appreciation for houses is not taxed. Given the rollover provision (capital gains from house sales that are reinvested in housing are tax-deferred) and the one-time exclusion of \$125,000 for people over age 55, this assumption is realistic.<sup>6</sup> These capital gains rules provide another tax incentive for housing.

Changing the taxation of housing would change the user cost of homeownership. Table 4.1 examines the user cost of homeownership under several potential policy reforms using plausible parameters taken from Poterba (1990). The first line in the table is the user cost under the current policy with deductible mortgage interest and property taxes, untaxed

imputed rents and lightly taxed housing capital gains (equivalent to equation (1)). For a high income taxpayer, the user cost of homeownership is 0.114. This user cost can be interpreted as the annual consumption flow from the house be worth 11.4 percent of the value of the house to cover the after-tax cost of capital, property taxes, depreciation, maintenance and risk. The second row of Table 4.1 has the user cost of homeownership with no income tax. Without an income tax, the consumption flow from the house must cover the gross interest rate and the full cost of property taxes. Thus, the user cost increases by 22 percent: relative to not having an income tax, the current personal tax system provides a 22 percent subsidy to homeownership. An alternative interpretation for the user cost without a tax system is that it represents the user cost with an income tax on economic income from owner-occupied housing in a housing market where competition drives economic profits to zero.'

Since abolishing the income tax is unrealistic, it is important to consider alternative policies that would increase the conformity between housing and other goods. The third and fourth rows of Table 4.1 have two incremental reforms of the tax treatment of housing. The third row has the user cost if mortgage interest and property taxes were not deductible. The user cost increases by 11.6 percent but is less than the user cost without an income tax. Eliminating the deductibility of interest and property taxes does not eliminate the tax subsidy to housing since the return to equity-financed homeownership is not taxed. The portion of an owner-occupied house that is equity financed is the value of the house that is clear of the mortgage. This policy favors equity finance over debt (mortgage) finance, since the cost of equity finance is  $(1 - \theta)i$  but the cost of debt finance is the gross interest rate,  $i$ . If homeowners increased their reliance on equity finance by borrowing less in response to eliminating mortgage interest deductibility, then this policy would increase the user cost by less than 11.6 percent.\*

The fourth row eliminates the rollover and exclusion provisions that virtually eliminate taxes on housing capital gains: housing capital gains are taxed upon realization like gains on other assets. The current deferral option of realization-based taxation lowers the effective tax rate on all capital gains. This option is assumed to reduce the statutory tax rate by 50 percent (see King and Fullerton (1984)), so the effective tax rate on housing capital gains is 14 percent? Increasing the conformity between capital gains on housing and other assets would only increase the user cost by 3.5 percent. Thus, the special capital gains provisions do not appear to play a large role in the tax subsidy to housing.

The last policy alternative addresses taxing the return on equity-financed housing by taxing the imputed rent from homeownership. It treats homeownership as a small business: the income from homeownership (imputed rent) is taxed but costs (interest, property taxes, depreciation allowances and maintenance) are deductible. Unlike eliminating interest deductibility, taxing the imputed rent favors neither equity nor debt finance. One problem with this policy is that designing depreciation allowances for personal residences would be

complicated. Furthermore, depreciation rules can often be exploited to reduce taxes.” Under the assumption that the present value of depreciation allowances is fifty cents for every dollar invested, treating homeownership as a small business increases the user cost by 19 percent.” With this set of parameters, this user cost approximately equals the user cost without an income tax. More generous depreciation allowances would decrease the user cost of homeownership.<sup>12</sup>

Since the user cost depends on the homeowner’s marginal tax rate, the subsidy from the tax system varies with a household’s income. For a household with a marginal tax rate of zero, the tax system does not affect the user cost. For a household with a 15 percent marginal tax rate, the tax subsidy to housing relative to not having an income tax is 9.7 percent rather than the 21.9 percent subsidy for households with a 28 percent tax rate. The overall subsidy to homeownership depends on the distribution of homeownership across income groups. Table 4.2 presents the weighted average tax subsidy for owner-occupied housing using data from the 1989 Consumer Expenditure Survey. Column (1) reports the income distribution of homeowners. More than half of homeowners are in the middle income group (\$15,000 to \$50,000 of income) that roughly corresponds to the 15 percent marginal tax rate bracket. While only one-quarter of homeowners have incomes above \$50,000, this high income group owns 41 percent of the value of owner-occupied housing. Weighting the tax subsidy for homeownership for each income class by the share of the housing capital stock owned by the income class produces a weighted average tax subsidy for the total stock of owner-occupied housing of 13.3 percent.

Along with the previously mentioned caveats on the user cost formula, these changes in the cost of homeownership are imprecise for a number of reasons. First, the calculation of the change in the long-run after-tax cost of homeownership assumes that the supply of housing is perfectly elastic. This incidence assumption implies that a reduction in the subsidy is borne by future homeowners rather than the builders or current owners. While this assumption follows previous analyses of the tax subsidy (e.g., Aaron (1972)), White and White (1977) show that both the distributional effects of the subsidy and the change in the quantity of housing depends critically on the supply elasticity of housing. In contrast to the case of perfectly elastic supply, if the supply of housing was perfectly inelastic, then changes in the tax subsidy would be capitalized into current house prices and the incidence of the changes would be entirely on current homeowners. Since the quantity of housing does not change in this case, the tax subsidy would be expected to have little effect on energy demand. Intermediate values of the supply elasticity cause a mixture of these two cases. However, since the perfectly elastic supply case has the largest changes in the cost of homeownership and the quantity of housing, it produces the largest possible interaction of the tax subsidy and residential energy demand.

Second, the changes in the user cost depend on the choice and stability of the parameters (e.g., the interest rate) in the user cost. For example, lower interest rates or

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property tax rates would reduce the effect of eliminating deductibility of mortgage interest or property taxes. Moreover, changes in tax policy towards housing might affect the gross interest rate or the reliance on property taxes by local governments. The implicit incidence assumption is that tax policy towards housing does not affect the interest rate or other components of the user cost.

Third, although analyzing these tax reforms is easy, implementing them is difficult. The most comprehensive reform of treating homeownership requires measuring imputed rents, calculating depreciation allowances, and recording maintenance expenses. In part, this policy would increase the cost of tax compliance for homeowners. However, valuing the imputed rents from owner-occupied housing creates bigger problems than just recordkeeping: for many houses, a market rental value is hard to estimate. In addition to the economic complications of these reforms, increasing the tax burden on homeownership would face political obstacles: since the mortgage interest deduction has long been a “sacred cow” in tax policy, the political possibility of taxing imputed rent seems remote.

Overall, eliminating the tax subsidy to homeownership in the personal tax code by taxing imputed rents would raise the user cost of homeownership by about 20 percent. These estimates of the size of the tax subsidy roughly conform to those in the previous literature (e.g., Aaron (1972) and White and White (1977)). Incremental reforms, such as eliminating mortgage interest deductibility, would increase the user cost by less than 12 percent. Given the assumptions underlying these estimates, they provide upper bounds on the effect of tax policy on the cost of homeownership. These policies would directly effect the two-thirds of Americans who own their homes; however, as discussed in the next section, these policies should be analyzed in conjunction with the tax treatment of rental property.

### **Tax Incentives & Rental Property**

Since individuals choose whether to rent or own their homes, tax policies that affect the user cost of homeownership cannot be completely separated from the tax treatment of rental property. For renters, rents depend on the user cost of rental property. Raising the cost of homeownership but not the user cost of rental property would induce individuals to switch from owning to renting their homes.<sup>13</sup> For individuals who switch from owning to renting, the cost of rental housing is greater than the user cost before the change in policy but less than the cost of homeownership after the policy change. Thus, the endogeneity of tenure status would dampen the reduction in housing investment induced by raising the user cost of homeownership.

This endogeneity complicates analyzing the interaction between the tax treatment of housing and residential energy demand. Ignoring the shift from owning to renting that would occur with the elimination of the tax subsidy for owner-occupied housing would overstate the policy’s effect on energy demand. Adjusting for the changes in tenure status would require

simultaneously estimating changes in tenure status and amounts of residential energy. Another option for the analysis is to simultaneously change the tax treatment of rental property such that rents would increase by the roughly the same proportion as the user cost of homeownership. This option allows for the aggregation of rental and owner-occupied housing. The advantage of aggregating rental and owner-occupied housing is that the general equilibrium tax effects discussed below do not distinguish between rental and owner-occupied housing. Section 3 analyzes energy demand by owner-occupiers ignoring the tenure decision and energy demand by all households.

The user cost of rental property depends on the tax treatment of landlords.” The user cost for rental property depends on the landlord’s tax rate rather than the residents. The landlord’s tax rate could differ from the tenant’s either because tax rates are graduated or because only the landlord itemizes deductions. With competition between landlords, rents depend on the tax code. Unlike owner-occupied housing, the rents from rental property are taxed: the renter pays with income that is subject to the income tax and the landlord pays taxes on rents received. While this provision increases the tax burden on rental housing, rental property has a number of tax advantages relative to owner-occupied housing. As a business, the landlord can deduct maintenance expenses, property taxes, interest payments and depreciation allowances from income. The resulting user cost of rental property is:

$$\frac{c_r}{P_r} = [(1 - T)i + \delta + \alpha + - \pi_s] \frac{1 - zT}{1 - T} + \tau_p + m \quad (2)$$

where  $T$  is the landlord’s marginal tax rate,  $z$  is the present value of depreciation allowances for \$1 of investment,  $c_r$  is the value of consumption from the rental property,  $P_r$  is the price of rental property, and other terms are defined as in equation (1).

The tax treatment of rental property as a business is similar to the policy proposed in the fifth row of Table 4.1: taxing rents but allowing deductions raises the user cost of homeownership by 19 percent. However, separating who owns the home from who lives there creates a possible tax advantage for renting. An individual can choose between being an owner-occupier without the taxation of imputed rents or renting from a landlord who values depreciation deductions highly because of a high marginal tax rate (see Gordon, Hines and Summers (1987)). This tax arbitrage opportunity between high tax bracket landlords and low tax bracket renters could exist even if homeownership is taxed as a small business. Depending on the parameters (e.g., generosity of depreciation allowances), the effective tax rate on housing can either rise or fall with the marginal tax rate. The effective tax rate is the percentage difference between the user cost with the tax system and the user cost without a tax system. For example, if investing one dollar generates depreciation allowances with a present value of one dollar, then increasing the tax rate decreases the user

cost (and the effective tax rate) because high tax rate investors have a higher value of the interest deductions (i.e., a lower after-tax opportunity cost of capital).

As an example of why some people might prefer to rent for tax reasons, consider a person with a tax rate of zero who can rent from a landlord with a tax rate of 45 percent and depreciation allowances with a present value of 70 cents for each dollar of investment. These parameters roughly correspond to U.S. tax policy before 1986 (see Gordon, Hines and Summers). The person with the zero tax rate has a user cost of homeownership of 0.139. In contrast, for the landlord, the user cost of rental property is 0.126. The low tax rate person has an incentive to rent because the landlord has a lower after-tax opportunity cost of capital. Relative to homeownership, renting lowers the individual's cost of housing by 9.4 percent  $((0.139 - 0.126)/0.139)$ .

In analyzing the effect of the tax treatment of housing on energy demand, one needs to know whether to apply the tax subsidy to only owner-occupied housing or to a broader measure of the housing stock. As this example demonstrates, the tax treatment of landlords can lower rents. In section 3, I use two measures of the size of the housing capital stock affected by the tax code: (1) assuming that the tax policy only addresses the personal tax code subsidy to homeownership and that tenure choices do not change, I analyze the effect only on the current stock of owner-occupied housing; and (2) assuming that the policy change simultaneously addresses the tax treatment of landlords, I analyze the effect of the subsidy on the entire housing capital stock.

In terms of changing the user cost formula, policy reforms aimed at rental property are more subtle than those aimed at owner-occupied housing. Slower depreciation allowances, stricter anti-tax shelter provisions, and a narrower spread between the tax rates of landlords and tenants would all increase the user cost of rental property. The Tax Reform Act of 1986 included all three of these changes to some degree (see Poterba (1990)). The user cost of rental property after 1986 is much closer to the user cost without a tax system. Assuming that the present value of depreciation allowances fell to 50 cents per dollar invested and that the marginal landlord has a tax rate of 28 percent, the user cost of rental property is 0.136 or a subsidy of 2.2 percent relative to not having an income tax.<sup>15</sup>

In considering changes in the tax treatment of owner-occupied housing, treating homeownership as a small business serves as a natural benchmark if imputed rents are taxed, then housing faces the same level of taxation as nondurable consumption. For rental property, however, there is not an obvious benchmark policy. The calculation of the 2.2 percent subsidy uses the user cost without a tax system as a benchmark. Another comparison is between the tax treatment of rental property and other investments: does rental housing have a higher or lower effective tax rate than other uses of capital? However, comparisons with other investments introduce concerns regarding corporate level taxation of many alternative investments. The next section compares the level of taxation of housing and other capital.



**General Equilibrium Effects**

While the decision between renting and owning depends on the difference between the user costs for owner- and renter-occupied housing, the effect of the tax system on the amount of housing depends on the levels of the two user costs relative to the after-tax cost of other consumption goods and the returns to other investments. As shown above, relative to nondurable consumption, the weighted average tax subsidy from the personal tax code for owner-occupied housing is 13.3 percent and the subsidy for rental housing is 2.2 percent.”

Comparing housing with other investments is more complicated than comparing housing with other consumption because of the variation in the taxation of alternative investments. One simple breakdown is to compare investments in non-corporate and corporate capital. Residential structures are 46 percent of the total private capital stock.” Non-corporate residential structures account for 79 percent of noncorporate capital and corporate residential structures are less than 1.5 percent of total residential capital. Hence, dividing the private capital stock into two groups, corporate nonresidential capital and noncorporate residential capital, is a fairly accurate simplification.

Even with this simple division of capital, calculating the tax differential between the two groups is difficult. The statutory corporate income tax rate might differ greatly from a true measure of the extra tax burden imposed by the corporate tax system because of complicated interactions between depreciation rules, financial structure (e.g., the choice between debt and equity finance), inflation and the tax rate schedule.” To include these interactions, economists typically calculate effective tax rates to measure the tax burden on capital. Effective tax rates measure the difference between the marginal product of capital and the after-tax return to the owner of capital. The difference between the effective tax rates on corporate and noncorporate capital measures the extra tax burden imposed by the corporate tax system.

Estimating effective tax rates is an imprecise science. I rely on two previous measures of the difference between the effective tax rates on corporate and noncorporate assets. First, Fullerton, Gillette and Mackie (1987) calculate an effective tax rate of 44.4 percent on corporate assets and 33.9 percent (excluding owner-occupied housing) on noncorporate assets. These effective tax rates suggests that the corporate tax system increases the tax burden on capital by 10.5 percentage points relative to the tax treatment of noncorporate capital. Second, Fullerton and Karayannis (1992) estimate an effective tax rate on corporate capital of 42.3 percent and an average tax rate on income from rental property of 26.0 percent. The difference between these two tax rates, 16.3 percentage points, measures the extra tax burden on corporate assets that accounts for the mix of assets, financial choices and depreciation rules. These estimates suggest that housing (noncorporate) capital faces tax rates that are about 13 percentage points less than the tax rates on corporate capital.

This difference is in addition to the tax advantages of housing that arise from the personal tax system.

***Total Tax Subsidy on Housing***

The tax treatment of homeownership, rental property and corporate capital combine to create a wedge between the pre-tax marginal product of corporate capital and the after-tax return to housing. This wedge is the total subsidy to housing from the tax system. The previous sections have given some of the details on each component of this wedge; however, these different tax provisions can be summarized as a subsidy at a rate  $s$  on the return to housing relative to the pre-tax return to corporate capital:

$$r_c = (1 + s) r_h \quad (3)$$

where  $r_c$  is the pre-tax return to corporate capital and  $r_h$  is the rate of return to housing before taxes (price appreciation plus consumption value as a fraction of the total value of the house). This simple formula averages across rental and owner-occupied housing and across individuals with different tax rates.

Table 4.3 aggregates the different elements of the favorable tax treatment of housing into a single measure of  $s$ . Column (1) of the table summarizes the personal tax advantages to owner-occupied and rental housing. The personal tax advantage is the difference between the tax treatment of housing and other non-durable consumption goods. To aggregate to the tax subsidy on all residential capital, the tax advantages to owner-occupied and rental housing are weighted by their shares in the housing stock. Column (2) is a rough estimate of the difference the taxation of noncorporate and corporate capital. This difference is the relative taxation of corporate capital and noncorporate capital that is subject to the personal income tax. Column (3) is the total tax advantage of housing relative to corporate assets, the sum of columns (1) and (2).

Table 4.3 suggests that the tax system reduces the price of residential capital by 23 percent relative to corporate capital. Much of this price reduction is concentrated on owner-occupied housing because of the favorable personal tax treatment of homeownership. The subsidy for owner-occupied housing is 26.3 percent relative to 15.2 percent for rental housing. About half of the subsidy for owner-occupied housing and the majority of the subsidy for rental property come from the difference in taxation of corporate and noncorporate assets.

While these parameters combine to yield a best guess of the magnitude of the favorable tax treatment for housing, the exact size of the subsidy is uncertain. Both the user cost calculations and the effective tax rates between corporate and noncorporate capital are

sensitive to assumptions about parameters. These parameters, such as interest rates and tax rates, change over time. Furthermore, some of the favorable tax treatment depends on specific financing arrangements that may be endogenous to tax policy. For example, if mortgage interest rates are higher than the return to savings for individuals, then the user cost of homeownership depends on the amount of borrowing which depends on tax rules for deductibility. Despite these uncertainties, the estimates in Table 4.3 roughly approximate the tax subsidy to housing.

## 4.2 THE COMPOSITION OF RESIDENTIAL ENERGY USE

The size of the subsidy to housing from the tax system is one of two main elements in the interaction of the tax treatment of housing and energy demand. The other main element is the nature of residential energy demand. Residential energy consists of electricity (61%), natural gas (29%), oil (7%) and other sources (3%).<sup>19</sup> Residential energy encompasses a variety of end uses: space heating, air conditioning, water heating, kitchen appliances, lighting, and other miscellaneous energy needs. Table 4.4 reports the breakdown of residential energy demand by end use, by region of the country, and house size for 1987. These data are from the Residential Energy Consumption Survey. The average U.S. household consumes 162 million BTUS of energy.<sup>20</sup> Space heating is the largest component of residential energy demand covering 38 percent of the total. Air conditioning accounts for another 9 percent of residential energy demand. Energy use for heating and cooling varies greatly by region indicating the importance of climate for residential energy demand.

Miscellaneous energy demand, a broad category that includes such items as kitchen appliances and lighting, is the second largest category. Table 4.5 details the main categories of miscellaneous demand for electricity. Electricity accounts for over 93 percent of the total miscellaneous energy demand.<sup>21</sup> Kitchen appliances are the most important group within the miscellaneous category using 48 percent of miscellaneous electricity. Other than refrigerators, which use almost one-third of all miscellaneous electricity, no single appliance accounts for over 10 percent of the miscellaneous electricity demand.

While these statistics provide a useful summary of residential energy demand, the question remains whether they help in assessing the interaction between the tax subsidy and energy demand. How do the changes in housing capital induced by the tax subsidy affect these different categories of energy demand? One obstacle in answering this question is that increased expenditures on housing can purchase many different positive characteristics: more rooms, a better location, a larger yard, more modern appliances are just a few of the dimensions of house quality.<sup>22</sup> Some house characteristics, such as location and yard size, have little to do with energy demand. Other characteristics can either increase or decrease energy demand: for example, size is positively related with energy demand but newer (or more recently renovated) houses use less energy than older houses.

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Of the characteristics that increase energy demand, size is the easiest to compare with energy use. Table 4.2 shows a strong positive relation between size and total energy use: increasing from the 1000- 1600 square foot range to the 2000-2400 square foot range increases average energy demand by about 30 percent. However, the relation between energy use and house size depends critically on the end use: energy for space heating and miscellaneous uses increase considerably with house size, but water heating displays a much weaker relation with house size. Also, this comparison does not control for other determinants of energy demand that are correlated with house size, such as the number of people in the household. For example, even though larger houses are associated with using more energy to heat water, the relation between number of people in the household and energy for hot water is much stronger than the relation with size: the typical 4 person household uses 48 percent more energy for hot water than the typical 2 person household.<sup>23</sup> Within the miscellaneous category energy for some appliances, such as televisions, might have little relation with house size but be strongly related to the characteristics of the occupants.

Another house characteristic that might increase both house prices and energy demand is the number of miscellaneous appliances. Adding an appliance such as a dishwasher increases the value of the house but also increases the demand for energy. By subsidizing consumer durables, the tax system encourages individuals to increase the number of appliances in their homes. However, it is difficult to distinguish between the tax subsidy to homeownership and the tax subsidy to other durables. Consumer durables other than housing receive the same type of subsidy as owner-occupied homes: the implicit rental income from durables is not taxed. The distinction between the imputed rents from owner-occupied housing and durables within the house highlights a major problem in taxing imputed rents from owner-occupied housing: does the imputed rent include the contents of the house? If not, then a bias arises in favor of appliances rather than structures.<sup>24</sup> If imputed rents from household durables are taxed, then logically the tax on imputed rents should extend to other durables, such as cars.

At least two positive housing characteristics reduce, rather than increase, energy demand: energy efficiency and vintage. Dinan and Miranowski (1989) find a positive relation between house prices and energy efficiency. Their estimates imply that the housing market capitalizes improvements in energy efficiency at a 10 percent real discount rate.<sup>25</sup> Since the tax subsidy reduces the cost of housing capital including any efficiency improvements, the tax treatment of owner-occupied housing encourages investments in energy efficiency. Similarly, hedonic models of house prices reveal that, holding other characteristics fixed, newer houses are more valuable. Newer houses also use less energy than older houses: houses built after 1980 use one-third less energy for heating (controlling for climate and house size) than houses built between 1950 and 1969.<sup>26</sup> This statistic suggests that to the extent that tax subsidy encourages a newer housing stock, it reduces residential energy demand.

The net effect of the interaction between these different housing characteristics, the tax subsidy and energy demand is ambiguous. The model discussed in the next section treats housing capital as a substitute for energy in producing housing services. As will be discussed below, previous estimates of the substitutability between housing capital and residential energy suggest that there can only be limited substitution between capital and energy.

### 4.3 JOINT DEMAND FOR HOUSING AND RESIDENTIAL ENERGY

The amount of housing capital is directly tied to the amount of residential energy consumed. In modeling the relation between housing and residential energy, Quigley (1984a) posits a production function for housing services with two inputs: housing capital (real estate) and energy. In turn, housing capital is a function of land and structures. Quigley is mainly interested in how the increases in energy prices in the 1970s and 1980s affected the demand for residential energy, real estate and housing services. However, the estimated parameters can also be used to predict how tax policies that change the price of housing capital would affect residential energy.

Quigley models the supply of and demand for housing services in a competitive market. Housing services are produced from a nested constant elasticity of substitution (CES) production function combining land, structures and operating inputs.<sup>27</sup> First, land and structures combine through a CES production function to produce housing capital. Second, housing capital and operating inputs (energy) combine through a CES production function to produce housing services. The production function has constant returns to scale, so competition implies a perfectly elastic supply of housing services. With competition, the supply price of housing depends on input prices. Increasing the price on an input causes a substitution away from that input (for a given level of housing services) and increases the price of housing services.

Quigley estimates the quantity of housing services with a log-linear demand curve that depends on household income and the price of housing services implied by the production function. The model is estimated using 7378 observations on new home sales from Federal Housing Administration insurance records for 5 metropolitan areas from 1974 through 1978. The advantage of using data from 1974 through 1978 is that relative input prices changed dramatically over the period: real energy prices rose by almost 40 percent. Only having data on new homes is a mixed blessing. The disadvantage is that the results might not reveal changes in the value of existing homes. The advantage is that new house designs are more likely to be affected by changes in relative input prices. Since the estimates capture how house designs reflect relative prices, they are long-run estimates of changes in the housing stock. The estimated income elasticity for housing services is 0.34 and the estimated price elasticity is -0.72.<sup>28</sup>

Unlike previous studies, Quigley also estimates an elasticity of substitution between capital and energy. This elasticity of substitution is estimated as 0.32 suggesting some latitude for trading between capital and energy in producing housing services.<sup>29</sup> Based on the estimates of the substitutability of capital and energy and the demand parameters, a 10 percent increase in energy prices is associated with a 0.9 percent decline in the demand for housing services, 0.6 percent decline in the demand for real estate and a 2.8 percent decline in the demand for residential energy. This result suggests that policies targeted at changing the price of energy (i.e., corrective energy taxes) would reduce energy demand without greatly affecting the amount of housing capital.

The effect of eliminating the tax subsidy to housing on residential energy demand requires asking the opposite question from Quigley: instead of estimating how increases in energy prices affect the demand for housing services, removing the tax subsidy increases the price of housing capital which lowers demand for housing services which includes residential energy. For various changes in the price of housing capital (real estate), Table 4.6 reports the change in demand for housing services, real estate, and residential energy. For the 23 percent increase in housing prices implied by eliminating the tax advantage to housing (see Table 4.3), the demand for housing services would fall by 11.8 percent, the demand for real estate by 12.7 percent and the demand for residential energy by 6.8 percent. Thus, changing from the current tax system to one with neutral treatment between corporate and residential capital would reduce residential energy demand, though the effect might not be especially large. In comparison, a tax on residential energy that increased the price by 20.0 percent would induce the same reduction in residential energy demand. While a 20.0 percent tax on residential energy would induce the same reduction in energy demand, this tax is not a perfect substitute for eliminating the tax advantage of housing capital because the tax subsidy to housing varies with income (since marginal tax rates depend on income) but the energy tax would not vary by income.

The various entries in Table 4.6 correspond to alternative changes in the tax system that increase the relative price of housing capital and energy by more or less than 23 percent. Table 4.7 summarizes the effects on residential energy demand of the aforementioned policies and several alternatives. Addressing the personal tax advantage to housing without raising the tax on houses to the level of the tax on corporate capital would increase the price of housing capital by 10 percent and reduce the demand for residential energy by 3.2 percent. Only raising the tax on owner-occupied housing to the level of taxation on corporate capital would increase the price of owner-occupied housing by 26 percent. Ignoring the endogeneity of tenure choice, this policy would reduce the demand for residential energy by owner-occupiers by 7.5 percent.<sup>30</sup> However, since owner-occupiers only account for 74 percent of total residential energy demand, the total reduction in residential energy demand would be only 5.6 percent.<sup>31</sup>

Eliminating the deductibility of mortgage interest and property taxes -- a reform that only addresses part of the tax advantage of homeownership -- would have little effect on residential energy demand. Assuming that 70 percent of middle income homeowners itemize deductions and 100 percent of high income homeowners itemize deductions, eliminating the deductibility of mortgage interest and property taxes would increase the weighted average price of housing by 6.7 percent. This increase in the price of housing capital would lower the demand for owner-occupied housing by about 4.3 percent (ignoring any effects on tenure choice) and the demand for residential energy by homeowners by 2.9 percent or a 2.1 percent reduction in total residential energy demand.

The change in residential energy demand induced by a change in the price of housing capital can be decomposed into two parts. The first effect is the change in energy demand for a change in the level of housing services with relative input prices constant. If the demand for housing services fell by 11.8 percent without the change in relative prices, the demand for residential energy would also fall by 11.8 percent.<sup>32</sup> The second effect is a substitution effect from the change in relative prices. Given a decrease of housing services by 11.8 percent, the substitution of energy for capital induced by the increase in the price of housing capital increases the demand for residential energy by 5.0 percent (relative to energy demand before the decrease in housing services). The net effect of eliminating the favorable tax treatment of housing would be a 6.8 percent decrease in residential housing. However, this effect is much smaller than would be the case if one ignored the substitutability between housing capital and residential energy.

#### 4.4 FURTHER ISSUES IN HOUSING AND ENERGY DEMAND

Increasing the level of taxation on housing to approximately the same as the taxation of other consumption goods and corporate investments lowers the demand for housing services and, consequently, lowers the demand for residential energy. The 6.8 percent reduction in residential energy demand from eliminating the tax differential between housing and corporate capital is a 1.4 percent reduction in total U.S. energy consumption if energy used in other sectors of the economy does not change. However, this assumption -- that energy demand in other sectors is constant -- is suspect. A 11.8 percent reduction in housing services would probably be accompanied by increased investment in other activities and increased consumption of other goods. The net effect on total energy demand depends on the increased energy demand associated with this increased investment and consumption.

The changes in investment and consumption induced by the increased taxation of housing create a labyrinth of general equilibrium effects. While a many-sector full general equilibrium model of the economy might provide a rough estimate of these energy effects, tracing the exact change in total energy use from these effects is beyond the scope of this paper.<sup>33</sup> However, it is possible to put the potential reduction in residential energy in the context of the energy required for other consumption goods.

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Energy required for final consumption of a good takes two forms: (1) energy used by individuals in consuming the good (e.g., gasoline for a car) and (2) energy used to produce goods and services. Input-output analysis measures the energy used introducing goods and services. This analysis measures both the energy used directly introducing a good and the energy used in producing the inputs to the goods. Hannon, Blazeck, Kennedy and Illyes (1983) calculate energy intensities for 88 sectors in the economy. Compared to other goods, construction only uses a moderate amount of energy. The most energy intensive goods are chemicals, road construction, metal manufacturing, and transportation services.<sup>34</sup> Food, wood products (except paper), office machinery, and services (e.g., communications) are among the least energy intensive commodities. In terms of energy contained in different goods, it is unlikely that consuming less housing and more of other goods would greatly influence total energy demand. In general, changes in the product mix in the economy probably have only marginal effects on total energy used in production of goods.<sup>35</sup>

The analysis of the tax treatment of housing in sections 1 and 3 ignores tax incentives targeted at improving energy efficiency. The user cost and general equilibrium models focus on the traditional public finance arguments of why housing is tax-favored. However, in the past, the Federal tax code and many state tax codes have had specific incentives for investment in energy efficient housing. The Energy Tax Act of 1978 provided a tax credit of 15 percent of the investment (with a maximum credit of \$300) for energy conservation measures such as adding insulation.<sup>36</sup> The credit was in effect from 1979 through 1985. Previous research on the effectiveness of energy tax credits has been inconclusive (for a summary, see Hassett and Metcalf (1992)). Hassett and Metcalf (1992) analyze the effect of energy conservation tax credits allowing for uncertainty in energy prices and irreversibility of conservation investments. They find that while uncertainty in energy prices and irreversibility of investment lead to low level of conservation investment, the tax credit programs have a statistically significant positive effect on the amount of investment. These programs increase the tax subsidy to housing, but their targeted design results in increased energy conservation and possibly decreased energy use.

The model of the tax treatment of housing and residential energy demand increasing the price of capital in a constant elasticity production function between housing capital and energy abstracts from a wide variety of potential side-effects from changing the tax treatment of housing. Building codes may prevent free substitution between energy and capital implied by the unconstrained constant elasticity of substitution production function. If building codes prevent this substitution, then the model overstates the substitution effect of the increased price of capital and residential energy demand might decrease by more than 6.8 percent. Quigley (1984b) finds that the standards adopted by the California Energy Commission in 1980 would result in a larger reduction in energy consumption in response to a 10 percent increase in energy prices than would be implied by the substitution effect in the CES production function. The binding housing standards decrease individual welfare since the



individuals are forced to alter their choice of housing capital and energy however, this policy is justifiable if the market price of energy does not fully reflect society's value of energy.

Another side-effect that the model does not quantify is the possible effect on the organization of the housing market. Increasing the price of housing capital might have two effects on the organization of housing markets that indirectly decrease total energy demand. First, decreasing housing consumption might result in more centralized cities which would decrease energy used in transportation, especially commuting. Second, the smaller housing stock might correspond to fewer single family detached houses and more multifamily housing units that are more energy efficient. Assessing the importance of these indirect effects would be mere speculation.

## 4.5 CONCLUSION

This paper analyzes the effect of eliminating the favorable tax treatment of housing on the demand for residential energy. Residential energy is used for heating, cooling, cooking and many other appliances. Despite the wide variety of end uses, energy is a substitute for housing capital in producing housing services. Equalizing the taxation of noncorporate housing capital and corporate capital would increase the price of housing capital by 23 percent which would reduce residential energy demand by 6.8 percent. While eliminating all of the tax advantages of housing would substantially decrease residential energy use, it would not substantially affect total energy demand: residential energy is only 20 percent of total energy use and increased energy demand caused by the substitution to goods other than housing would offset, to some degree, the reduction in residential energy.

Analyzing the interaction between the tax treatment of housing and energy demand is important for tax policy for two reasons. First, although it is unlikely that the U.S. will revoke the tax advantages of housing by reforming the income tax system in the near future, the tax differential between housing and other goods could be eliminated through a number of other policy reforms. Examples include: (1) integrating the corporate and personal tax systems which would eliminate the tax differential between corporate and noncorporate capital; and (2) replacing the personal income tax with a consumption tax that taxes imputed rents from owner-occupied housing.<sup>37</sup> Second, the interaction between housing and energy highlights the importance of the tax treatment of substitutes and complements in designing tax policies aimed at reducing externalities. Eliminating the favorable tax treatment of housing has roughly the same effect on residential energy demand as a 20 percent tax on residential energy.

Table 4.1: User Cost of HomeOwnership Under Various Tax Policies		
Description of policy (User cost formula)	Implied user cost for high income taxpayer	Percentage change from current policy
1. Current policy (equation 1 in the text) $(1 - \Theta)(i + \tau_p) + \delta + m + \alpha - \pi_e$	0.114	--
2. User cost without an income tax $i + \tau_p + \delta + m + \alpha - \pi_e$	0.139	+21.9%
3. Eliminate deductibility of mortgage interest and property taxes $(1 - \Theta)Ei + (1 - E)i + \tau_p + \delta + m + \alpha - \pi_e$	0.127	+11.6%
4. Eliminate rollover and exclusion provisions for nominal capital gains on housing $(1 - \Theta)(i + \tau_p) + \delta + m + \alpha - \pi_e + \tau_{cg}\pi_e$	0.118	+3.5%
5. Tax imputed rents, allow deduction for mortgage int., prop. tax, dep'n and maintenance $[(1 - \Theta)i + \delta + \alpha - \pi_e](1 - z\Theta)/(1 - @) + \tau_p + m$	0.136	+19.3%

The following parameters are taken from similar calculations in Poterba (1990): a nominal interest rate,  $i$ , of 7 percent; a property tax rate,  $\tau_p$ , of 2 percent of the property value; a depreciation rate,  $\delta$ , of 2.5 percent; maintenance costs,  $m$ , of 1.4 percent; a risk premium for housing,  $\alpha$ , of 4 percent; and an expected inflation,  $\pi_e$ , of 3 percent. The marginal tax rate on ordinary income,  $\Theta$ , is assumed to be 28 percent. In the case that eliminates the rollover and exclusion provisions, the accrual equivalent effective tax rate,  $\tau_{cg}$ , is assumed to be one-half of the ordinary income tax rate (14 percent) to reflect the value of deferral. When the user cost depends upon the size of the mortgage, the equity-to-value ratio,  $E$ , is taken as 60 percent which roughly corresponds to the average value for the 1980s from the Federal Reserve Board's Flow of Funds and Savings Section, 1988 (see Manchester and Poterba (1989)). The parameter  $z$  accounts for the present value of the depreciation allowances for \$1 of investment. Following Gordon, Hines and Summers (1987),  $z$  is approximated as 0.5.

These calculations are made under two assumptions. First, the supply of housing is infinitely elastic, so the tax (subsidy) falls on the consumer. Second, the changes in tax policy do not affect the nominal interest rate, the risk premium, or the property tax rate.

Table 4.2: Weighted Tax Subsidy for Owner-occupied Housing					
Income Class:	% of owner- occupiers (1)	\$ billion (2)	% of owner- occupied housing stock (3)	Tax subsidy for income class (4)	Weighted average <b>tax</b> subsidy (3) x (4)
Low income (tax rate = 0%) Income < \$15000	22.5%	788.00	15.3%	0.0%	0.0% -
Middle income (tax rate = 15%) \$15000-\$50000	52.1%	2231.25	43.4%	9.7%	4.2%
High income (tax rate = 28%) Income > \$50000	25.3%	2123.20	41.3%	21.9%	9.1%
Total for all income groups	99.9%	5142.45	100.0%	---	133%

Source: Consumer Expenditure Survey (CES) for 1989 for income distribution of tenure status and house values. Column(1) is the percentage of households in the income class that own their homes. Column (2) is the estimated value of homes owned by households in the income class from the CES. Column (3) is the percentage of the total value of the owner-occupied housing stock owned by households in the income class (the entry in column (2) divided by \$5142.45 billion). Column (4) are the tax subsidies for homeownership for the income class. These subsidies are from author's calculations using user cost formula similar to table 1. For owners, the percentage subsidy is the percentage increase in the user cost of moving from line 1 of table 1 to line 2 of table 1 for different marginal tax rates.

<b>Table 4.3: Total Tax Subsidy to Housing Relative to Corporate Assets</b>			
	Personal Tax Advantage (1)	Corporate Tax Advantage (2)	Total Tax Advantage (1) + (2) = (3)
Owner-occupied Housing	13.3%	13.0%	26.3%
Rental Housing	2.2%	13.0%	15.2%
Weighted Average for all Residential Capital	10.0%	13.0%	23.0%

Weights for owner-occupied (70%) and rental housing (30%) are from the Survey of Current Business, August 1990, Table 9, page 101. The personal tax advantage for owner-occupied housing is from the calculations in Table 2 (and described in the text). The personal tax advantage for rental housing is described in section I.B. The corporate tax advantage is the an average from the difference in the effective tax rates on corporate and noncorporate capital taken from Fullerton, Gillette and Mackie (1987) and Fullerton and Karayannis (1992) (described in section I.C).

<b>Table 4.4 Composition of Residential Energy Use, By Region and Size of Unit, 1987</b>										
	Housing units	BTUs per housing unit	Space Heat BTUs %		Water Heat BTUs      %		Air Cond. BTUs      %		Misc. BTUs %	
National	90.5	161.9	60.7	38	233	15	14.4	9	61.1	38
By Region:										
Northeast	19.0	162.7	83.9	52	18.2	11	6.0	4	54.7	33
Midwest	22.3	170.0	73.8	44	23.8	16	11.7	7	60.7	36
South	30.9	163.0	45.2	28	25.1	15	26.7	16	65.7	40
West	18.3	131.2	39.2	29	24.5	19	6.0	5	61.1	47
By sq. footage:										
<999	32.3	114.3	42.9	38	20.1	18	9.2	8	42.1	37
1000-1600	25.6	155.8	54.1	35	24.4	16	15.1	10	62.1	40
1600-2000	11.2	183.9	70.6	38	24.2	13	18.4	10	70.6	38
2000-2400	8.4	201.7	79.5	40	25.9	13	17.7	9	78.6	39
>2400	13.0	233.8	98.9	42	26.1	11	23.8	10	85.1	36

Housing units are in millions. BTUS are in millions. Housing units include houses, apartments, mobile homes for both owner-occupied and renters. For comparability between site electricity BTUS and fossil fuel BTUS, site electricity BTUS are multiplied by three.

Source: Household Energy Consumption and Expenditures 1987, Part 1: National Data, Energy Information Administration, U.S. Department of Energy (1989), pages 89, 93, 95, and 98.

<b>Table 4.5: Miscellaneous Electricity Use, By Appliance, 1987</b>		
<b>Appliance:</b>	<b>Energy Use as a Percentage of Miscellaneous Electricity</b>	<b>Energy Use as a Percentage of Total Electricity</b>
Kitchen:	48.4	30.2
Refrigerators	31.8	19.8
Freezers	8.1	5.1
Range/Oven	6.1	3.8
Microwave Ovens	1.1	0.7
Dishwashers	1.3	0.8
Clothes Dryers	9.0	5.6
Clothes Washers	1.4	0.8
Televisions	9.2	5.7
Furnace Fans	6.0	3.8
Water-Bed Heaters	4.0	2.5
Other	22.9	13.2

Miscellaneous electricity use accounts for 62,4 percent of total electricity use.

The other category includes lighting, small cooking appliances, computers, electric tools, ceiling fans, electric blankets and other electric appliances.

Source: Household Energy Consumption and Expenditures 1987, Part 1: National Data, Energy Information Administration, U.S. Department of Energy (1989), page 10.



<b>Table 4.6: The Effects of Increasing the Price of Housing Capital</b>			
Increase housing capital price from a change in the tax treatment of housing	Associated Change in the Demand for:		
	Housing Capital	Housing Services	Residential Energy
5%	-3.1%	-2.9%	-1.6%
10%	-6.0%	-5.6%	-3.2%
13%	-7.7%	-7.1%	-4.0%
15%	-8.7%	-8.1%	-4.6%
20%	-11.2%	-10.4%	-6.0%
23%	-12.7%	-11.8%	-6.8%
25%	-13.6%	-12.6%	-7.3%
26%	-14.0%	-13.0%	-7.5%
30%	-15.8%	-14.7%	-8.5%
35%	-17.8%	-16.7%	-9.7%

Source: Author's calculations based on parameters estimated by Quigley (1984a).

<b>Table 4.7: The Effects of Alternative Policies on Residential Energy Demand</b>	
Policy Alternative:	Change in Residential Energy Demand
1. Raise the level of taxation on housing (owner-occupied and rental) to the level of taxation of corporate capital (A 23.0% increase in the cost of housing capital)	-6,8%
2. A 20% increase in the price of residential energy	-6.8%
3. Eliminate the personal tax advantage owner-occupied and rental housing with addressing the advantage created by the corporate tax (A 10% increase in the cost of housing capital)	-3.2%
4. Raise the level of taxation on owner-occupied housing to the level of taxation of corporate capital without addressing rental property (A 26.0% increase in the cost of owner-occupied housing)	-5.6%
5. Eliminate the deductibility of mortgage interest and property taxes for owner-occupiers (A 6.7% increase in the price of owner-occupied housing)	-2.1%

Source: Author's calculations from tables 3 and 6, as described in the text.

## REFERENCES

- Aaron, H. J., 1972, Shelter and Subsidies: Who Benefits from Federal Housing Policies, Washington, DC: Brookings Institution.
- Bradford, D. F., 1986, Untangling the Income Tax, Cambridge: Harvard University Press.
- Carlton, D. and G. Loury, 1980, "The Limitation of Pigouvian Taxes as a Long-Run Remedy for Externalities," Quarterly Journal of Economics, 94:559-566.
- Cordes, J. J. and H. Galper, 1985, "Tax Shelter Activity Lessons from Twenty Years of Evidence," National Tax Journal, 38:305-324.
- Council of Economic Advisors, 1991, Economic Report of the President, Washington, DC: U.S. Government Printing Office.
- Crandall, R., 1983, Controlling Industrial Pollution: The Economics and Politics of Clean Air, Washington, DC: Brookings Institution.
- Dinan, T. M. and J. A. Miranowski, 1989, "Estimating the Implicit Price of Energy Efficiency Improvements in the Residential Housing Market: A Hedonic Approach," Journal of Urban Economics, 25:52-67.
- Evans, J. S., 1984, "Cross-Sectional Mortality Studies and Air Pollution Risk Assessment," Energy International, 10:55-83.
- Fullerton, D., R. Gillette, and J. Mackie, 1987, "Investment Incentives Under the Tax Reform Act of 1986," in Compendium of Tax Research, 1987, Office of Tax Analysis, U.S. Department of the Treasury, 131-171.
- Fullerton, D. and M. Karayannis, 1992, "Tax Evasion and the Allocation of Capital," mimeo, Carnegie Mellon University.
- Gordon, R. H., J. R. Hines, Jr., and L. H. Summers, 1987, "Notes on the Tax Treatment of Structures," in The Effects of Taxation on Capital Accumulation, ed. by M. S. Feldstein, 223-254, University of Chicago Press.
- Goulder, L. H., 1992, "Do the Costs of a Carbon Tax Vanish When Interactions with Other Taxes are Accounted For?," National Bureau of Economic Research Working Paper No. 4061.
- Hall, D. H., 1990, "Preliminary Estimates of Cumulative Private and External Costs of Energy," Contemporary Policy Issues, 8(3):283-307.

- Hannon, B., T. Blazec, D. Kenedy, and R. Illyes, 1983, "A Comparison of Energy Intensities: 1963, 1967 and 1972," Resources and Energy, 5:83-102.
- Hassett, K. A. and G. E. Metcalf, 1992, "Energy Tax Credits and Residential Conservation Investment," National Bureau of Economic Research Working Paper No. 4020.
- Hausman, J. A., 1979, "Individual Discount Rates and the Purchase and Utilization of Energy-using Durables," Bell Journal of Economics, 10:33-54.
- Hoyt, W. H. and S. S. Rosenthal, 1990, "Capital Gains Taxation and the Demand for Owner-occupied Housing," Review of Economics and Statistics, 72:45-54.
- Johnson, R. C. and D. L. Kasserman, 1983, "Housing Market Capitalization of Energy-saving Durable Good Investments," Economic -21:374-386.
- Khazzoom, J. D., 1987, "The Demand for Insulation --A Study in the Household Demand for Conservation," The Energy Journal, 8:73-92.
- King, M. A. and D. Fullerton, 1984, The Taxation of Income from Capital, Chicago: University of Chicago Press.
- Krenz, J. H., 1976, "Energy per Dollar Value of Consumer goods and Services," IEEE Transactions on Systems, Man, @ Cybernetics, July, vol. SMC-4, 386-388.
- Lave, L. B., cd., 1982, Quantitative Risk Assessment in Regulation, Washington, DC: Brookings Institution.
- Lave, L. B. and E. P. Seskin, 1978, Air Pollution and Human Health, Baltimore: Johns Hopkins Press for Resources for the Future.
- Longstreth, M., A. R. Coveney and J. S. Bowers, 1985, "The Effects of Changes in Implicit Energy Costs on Housing Prices," Journal of Consumer Affairs, 19:57-73.
- MacRae, C. D. and M. A. Turner, 1981, "Estimating Demand for Owner-occupied Housing Subject to the Income Tax," Journal of Urban Economics, 10:338-356.
- Manchester, J. M. and J. M. Poterba, 1989, "Second Mortgages and Household Saving," Regional Science and Urban Economics, 19:325-346.
- National Academy of Sciences, 1991, Policy Implications of Greenhouse Warming, Washington, DC: National Academy of Sciences.
- New York State Energy Office, 1991, Draft New York State Energy Plan, Executive Summary.

- Nichols, A. L. and R. J. Zeckhauser, 1986, 'The Perils of Prudence,' Regulation, 10:13-24.
- Nordhaus, W. D. and G. P. Yohe, 1983,
- Palmquist, R. B., 1984, "Estimating the Demand for the Characteristics of Housing," Review of Economics and Statistics, 66:394-404.
- Poterba, J. M., 1984, 'Tax Subsidies to Owner-occupied Housing: An Asset-Market Approach,' Quarterly Journal of Economics, 99:729-752.
- Poterba, J. M., 1990, 'Taxation and Housing Markets: Preliminary Evidence on the Effects of Recent Tax Reforms,' in Do Taxes Matter? The Impact of the Tax Reform Act of 1986, ed. by J. Slemrod, 141-160, Cambridge: MIT Press.
- Poterba, J. M., 1991, 'Tax Policy to Combat Global Warming: On Designing a Carbon Tax,' in Global Warming: Economic Policy Responses, ed. by R. Dornbusch and J. M. Poterba, 71-98, Cambridge: MIT Press.
- Quigley, J. M., 1984a, 'The Production of Housing Services and the Derived Demand for Residential Energy,' Rand Journal of Economics, 15:555-567.
- Quigley, J. M., 1984b, "Residential Energy Standards and the Housing Market: A Regional Analysis," International Regional Science Review, 9:201-216.
- Quigley, J. M. and D. L. Rubinfeld, 1989, "Unobservable in Consumer Choice: Residential Energy and the Demand for Comfort," Review of Economics and Statistics, 71:416-425.
- Rosen, H. S., 1979, "Housing Decisions and the U.S. Income Tax: An Econometric Analysis," Journal of Public Economics, 11:1-23.
- Rosen, H. S., 1985, "Housing Subsidies: Effects on Housing Decisions, Efficiency, and Equity," in Handbook of Public Economics, volume 1, ed. by A. J. Auerbach and M. S. Feldstein, 375-420, North-Holland.
- Ruderman, H., M. D. Levine and J. E. McMahon, 1987, 'The Behavior of the Market for Energy Efficiency in Residential Appliances Including Heating and Cooling Equipment, The Energy Journal, 8:101-124.
- Schelling, T. C., 1983, "Climatic Change: Implications for Welfare and Policy," Changing Climate. Report of the Carbon Dioxide Assessment Committee, Washington, DC: National Academy Press.

----- 1991, "Economic Responses to Global Warming: Prospects for Cooperative Approaches," in R. Dornbusch and J.M. Poterba, eds., 1991, Global Warming: Economic Policy Responses Cambridge: MIT Press, pp. 197-221.

Schneider, S. H., 1989, Global Warming: Are We Entering the Greenhouse Century?, San Francisco: Sierra Club Books.

U.S. Department of Energy, 1989, Household Energy Consumption and Expenditures 1987, Part 1: National Data, Washington, DC: U.S. Government Printing Office.

U.S. Department of Treasury, 1992, Integration of the Individual@ Corporate Tax Systems: Taxing Business Income Once, Washington, DC: U.S. Government Printing Office.

White, M. J. and L. J. White, 1977, "The Tax Subsidy to Owner-Occupied Housing: Who Benefits?," Journal of Public Economics, 3:111-126.

Wilson, R. and E. A. C. Crouch, 1991, "Risk Assessment and Comparisons: An Introduction," Science, 252:522-528.

Woodward, S. E. and J. C. Weicher, 1989, "Goring the Wrong Ox: A Defense of the Mortgage Interest Deduction," National Tax Journal, 42:301-313.

Zeckhauser, R. J. and W. K. Viscusi, 1990, "Risk Within Reason," Science, 248(4955):559-563.

## NOTES

1. For a general discussion of a carbon tax, see Poterba (1991); Goulder (1992) has an extensive general equilibrium analysis.
2. Total annual cost equals the annualized cost of land and structures plus the annual operating expenditure on utilities (Table 1, p. 558, Quigley (1984a)).
3. Source: U.S. Energy Information Administration, State Energy Data Report, 1960-1988. Other end uses for energy were: commercial, 16%; industrial, 36%; and transportation, 28%.
4. As noted by Poterba and others, under the “benefit tax” view of the property tax (i.e., the property tax is a fee for local public services), it is not clear how the property tax should be treated in the user cost.
5. Also, the user cost reflects the marginal cost of housing rather than the average cost. This distinction arises when home-ownership induces the household to switch from taking the standard deduction to itemizing. In this case, the tax savings from using the standard deduction rather than itemizing are lost inducing a fixed cost to homeownership. This distinction is mainly important for the tenure decision, so it may not be important for energy demand.
6. For a sample of homebuyers who owned their previous home, Hoyt and Rosenthal (1990) report that 15 percent of the sample bought houses that were less valuable than their previous homes, so that they would not be completely covered by the rollover provision.
7. The nature of owner-occupied housing makes it somewhat difficult to distinguish between producer and consumer surplus. While competition drives the producer surplus to zero, the consumer surplus from owner-occupied housing may still be large.
8. For example, if the equity-to-value ratio increased from .6 to .7, then the user cost would only increase by 9.9%.
9. Two other tax provisions influence the effective capital gains tax on housing. First, the U.S. tax code allows a step-up in basis for assets that are inherited (constructive realization at death) that eliminates the capital gains tax on any appreciation of assets before inheritance. This provision lowers the effective tax rate on capital gains. Second, unlike other capital assets, individuals cannot deduct capital losses from the sale of property (e.g., houses or cars). This asymmetric treatment of housing capital losses and gains increases the effective taxation of housing capital gains. The justification for this tax rule is that the current tax code does not allow individuals to deduct depreciation on houses. Depreciation allowances would lower the basis of the house which would increase the size and frequency of housing capital gains. The current policy of not

allowing depreciation allowances is consistent with the policy of not taxing the imputed rents from homeownership.

10. Depreciation allowances create two tax-minimizing strategies: (1) borrowing to increase the sum of interest and depreciation deductions, a tax sheltering strategy often associated with partnerships (see Cordes and Galper (1985)); and (2) “churning” by which assets are sold frequently to increase the total value of their depreciation allowances when the tax system allows accelerated depreciation (see Gordon, Hines and Summers (1987)).

11. Depreciation allowances with a present value of fifty cents for every dollar invested roughly correspond to the present value of current depreciation allowances for business structures (using a discount rate of 6 percent). Currently, for tax purposes, business structures can be depreciated using straight-line depreciation over 27.5 years.

12. If the taxpayer received depreciation allowances with a present value of \$1 for each dollar invested ( $z = 1$ , in the formula in table 1), the user cost would only rise by 5%. The tax system would still provide a generous subsidy because the opportunity cost of capital is the after-tax return on bonds that are assumed to be taxed at the marginal tax rate for ordinary income. In contrast, if the taxpayer cannot deduct depreciation ( $z = 0$ ), the user cost would increase by 34%

13. Rosen (1979) estimates that taxing imputed rents for homeowners would decrease the incidence of homeownership by over 4 percentage points.

14. I implicitly assume that rental property is owned by individuals or partnerships rather than corporations. See Poterba (1990) for a summary of the debate on the marginal source of investment in rental housing.

15. As with homeownership, this subsidy is the same as the subsidy relative to an income tax on economic income with a perfectly competitive housing market and constant returns to scale production.

16. As discussed below, similar to owner-occupied housing, the imputed rents from consumer durables are not taxed.

17. The comparisons for different types of capital are for 1989 from the Bureau of Economic Analysis, Survey of Current Business, August 1990, page 101, tables 5 and 9.

18. For a rich description of these interactions, see King and Fullerton (1984).

19. Source: Office of Technology Assessment, Building Energy Efficiency, 1992, p. 17. These statistics mask the heterogeneity in sources for residential energy because electricity is generated from a variety of fuels.

20. For comparability between electricity BTUS delivered to houses and fossil fuel BTUS contained in natural gas, electricity BTUS are multiplied by three throughout the paper.



See Residential Energy Consumption Survey Trends in Consumption and Expenditures, 1978-1984, DOE, Energy Information Administration, 1987, pp. 14-15.

21. Source: Calculated (site electricity BTUs are adjusted to be comparable to natural gas BTUs) from table 1, p. 4 of U.S. Department of Energy (1989).

22. Hedonic regression techniques can be used to study the contributions of specific characteristics to the overall value of a good. Palmquist (1984) and Quigley and Rubinfeld (1989) are two recent examples of studies that apply hedonic techniques to house values. The results suggest that house size, number of rooms, age and neighborhood quality are among the most important determinants of house values.

23. Source: U.S. Department of Energy (1989), p. 110.

24. An analogous tension arises between the tax treatment of business equipment and structures: depreciation rules sometimes favor one type of investment over the other.

25. Johnson and Kasserman (1983), Longstreth, Coveney and Bowers (1985), and Khazzoom (1987) also report that energy efficiency increases house value. In contrast, the literature on energy savings in appliances suggests that consumers are myopic (see Ruderman, Levine and McMahon (1987) and Hausman (1979)). Hausman's estimates suggest that consumers discount appliance efficiency using a 30 percent discount rate.

26. Source: U.S. Department of Energy (1989), figure 6, page 12.

27. Operating inputs exclude maintenance expenses which are classified as a cost of capital.

28. These estimated elasticities are somewhat different than those found by Rosen [1979] who concentrates on the tax aspects of housing choice and finds an income elasticity of 0.76 and a price elasticity of -1.0. However, two differences in methodology might explain the variation in elasticities: (1) Quigley only uses data on new houses but Rosen uses a cross-section of existing homes; and (2) Rosen does not allow for a production function that combines housing capital and operating inputs. Using data on new houses, MacRae and Turner (1981) estimate an income elasticity of 0.25 and a price elasticity of -0.89 allowing for a production function that combines housing capital and operating inputs.

29. As noted by Quigley, this elasticity of substitution between capital and energy is lower than the elasticity of substitution between land and structures for producing housing capital.

30. Ignoring the endogeneity of tenure choice overstates the effects of the policy change on the demand for housing capital and residential energy.

31. The division of residential energy demand by tenure status is calculated from U.S. Department of Energy (1989), page 26, table 7.

32. If relative input prices are constant, the percentage decrease in residential energy demand equals the percentage decrease in housing services because the estimated production (constant elasticity of substitution) has constant returns to scale.

33. Constructing a general equilibrium model that adequately captures the interaction between housing capital, residential energy, the demand for other goods and investment in alternative investments would be a difficult task. Among the more complex features of the model would be knowing the degree to which lower consumption of housing increases consumption of other goods as opposed to investment in alternative assets. Furthermore, individuals could switch to investing abroad which would complicate the effects on energy demand since the problem would expand to include foreign and domestic energy use.

34. The input-output analysis only includes commercially-produced transportation services. Energy used by individuals to produce transportation is recorded as direct household consumption.

35. See Krenz (1976), page 387.

36. In addition, the Energy Act of 1978 provided larger credits for investment in solar, wind and geothermal energy equipment.

37. For a full explanation of the integration of personal and corporate taxation, see U.S. Department of Treasury (1992). For a discussion of the options of taxing consumption rather than income and the tax treatment of housing under different consumption tax plans, see Bradford (1986).